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NEW DIMORPHIC MUTANTS OF THE OENOTHERAS

HUGO DEVRIES

(WITH FIVE FIGURES)

Among the previously described mutants of *Oenothera Lamarckiana* Ser. there is a form which, although fertile with its own pollen, yields a dimorphic progeny. Some of the individuals exactly repeat the stature and characters of their parent, but others return to the type of *O. Lamarckiana*. Besides these, new mutants, especially *O. oblonga*, are relatively numerous. The two main types are produced in varying proportions, according to the individual cultures. The typical specimens may be as few as 10 per cent, or as numerous as 80 per cent. In most instances, however, they show a proportion of about 35–40 per cent. Considering the much smaller individual strength of the typical ones, as compared with the atavistic specimens, these figures may be regarded as indicating a splitting, ordinarily, into nearly equal parts.

This inconstant mutant is *O. scintillans*.[1] Exactly the same phenomenon of splitting has been observed recently in a number of new types. In the first place, in *O. stenomeres* mut. *lasiopetala*, described by BARTLETT.[2] In the second place, it has occurred in my own cultures, among the new mutants of *O. Lamarckiana*, as well as among those of another American species, described under

[1] The mutation theory. Chicago. 1909. Vol. I, p. 377; and Gruppenweise Artbildung, p. 257. 1913.

[2] BARTLETT, H. H., Mutations of *O. stenomeres*. Amer. Jour. Bot. 2:100–109; see also 2:146. 1915.

the preliminary name of *O. biennis Chicago*.[3] I shall deal with this one under the name *O. saligna*, and designate the new inconstant mutants of *O. Lamarckiana* as *O. cana*, *O. pallescens*, *O. Lactuca*, and *O. liquida*. As far as investigated, they all follow the rule that in every generation they split up into two ordinarily almost equal groups of typical specimens and of atavistic individuals which, in all cases, exactly duplicate the characters of *O. Lamarckiana*.[4] Moreover, they show a relatively high degree of mutability.

With one of them, *O. cana*, I have made a number of crosses with allied forms, in order to ascertain that it behaves in the same manner as *O. scintillans*, and that the same conception of heterogamy must be applied here also. In this mutant the pollen carries only the hereditary qualities of *O. Lamarckiana*, and the specific marks of the mutant are handed down to their progeny through the ovules only.[5] This conception of heterogamy may be considered to hold good for the other inconstant types also.

The same behavior is found in *O. lata*, but since this form never produces any fertile pollen in my cultures and has to be fertilized by *O. Lamarckiana* in order to produce seeds, the evidence which it affords is less stringent than that given by the self-fertile dimorphic races.

Oenothera Lamarckiana mut. *cana*.—Among a number of dubious mutants from *O. lata* which were cultivated as biennials in 1906–1907, a plant was noticed in the third generation of that family with narrower leaves of a gray color, evidently constituting a new type. It was very vigorous, reached a height of about 2 m., and was self-fertilized. It will be designated as *O. cana* from *lata* no. 1, since the first family of *O. cana* was derived from it.

Next year the same mutant type was recognized among the young rosettes, issuing from different samples of seeds of *O. lata* (fig. 1). All in all there were 5 specimens of *O. cana*. In order to determine the frequency of this mutant I have made two cultures

[3] Gruppenweise Artbildung, p. 52. *fig. 18* and *pl. 6*. 1913.

[4] In the wild condition such a splitting would evidently cause a race to die out after a few generations, especially since the atavists are very fertile and much stronger than the mutant form. As a matter of fact, inconstant wild species of this type are not known. See The mutation theory, Vol. I, p. 380.

[5] Gruppenweise Artbildung, p. 273. 1913.

on a sufficiently large scale, using the seeds produced by my pure strain of *O. lata* fertilized by *O. Lamarckiana*. The seeds of 1909 gave 564 seedlings, with 18 per cent *lata* and 2 per cent *cana*. Those of 1908 gave 1550 seedlings, 8 per cent of which were *lata* and 9 per

FIG. 1.—*Oenothera Lamarckiana* mut. *cana:* a young plant showing the narrow leaves by which it is easily distinguished from rosettes of the *Lamarckiana* type in the same sowings; June 11, 1915.

cent were *cana*. Other mutants appeared in these cultures in different proportions, as usual.

Among the seeds of pure *O. Lamarckiana*, *O. cana* is much the rarer. In 1913 I fertilized, on 5 strong biennial specimens, almost all the flowers during two months and got sufficient seed to have 20,000 seedlings in 1914. Of these only 6 were *cana*, giving a percentage of 0.03 per cent. In the same boxes 7 *rubrinervis* and 5

scintillans appeared as mutants, showing that the mutation coefficients for these three forms do not essentially differ from one another.

Stray mutations into *cana* have appeared in later years in different cultures, as, for instance, in 1913 in those of *O. laevifolia* and *O. scintillans*. Three mutations from *O. pallescens* will have to be recorded in the pedigrees relating to this form. It seems probable that *cana* mutants also have appeared in previous years, but have not been distinguished from other narrow-leaved types, of which there have always been quite a number in the larger cultures. Many other mutations also have escaped observation during a series of years until a single specimen developed into a strikingly new type.

I have cultivated *O. cana* mostly as annuals, but in some instances as biennials. In both cases the stature is the same as that of *O. Lamarckiana*, but in the annuals the stems are slender and the foliage rather loose, whereas the biennials have thick and strong stems with dense foliage. The leaves are narrow, with a shorter blade and a longer petiole, and of a very striking gray color. The flower buds are long and thin, contrasting sharply with those of *O. Lamarckiana* and even more so with those of *O. pallescens* and *O. Lactuca*. The spike is less dense than in the parent species and the fruits are more cylindrical and narrower, containing fewer seeds (fig. 2). In the flowering condition, as well as in the stage of young rosettes, the plants are now easily recognized, but at other periods of their development it is often difficult to identify and count them, some specimens showing their marks very clearly, but others resembling more or less their *Lamarckiana*-like sisters.

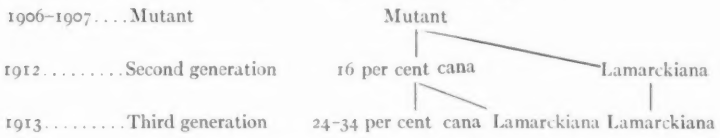
The easiest marks are afforded by the flower buds. Measured the day before opening and with the tube and ovary, their size varies, as a rule, from 75–80 mm., against 80–95 mm. in *O. Lamarckiana* cultivated under the same conditions; means 77.5 against 90 mm. The breadth, measured at the base of the conical part above the tube, is only 7 mm. The 4 tips at the top of the bud are more or less bent on one side, and this curious mark is so striking that it is often the first which draws the attention to a stray mutant of the *cana* type (fig. 2). The 4 lobes of the stigma are

FIG. 2.—*Oenothera Lamarckiana* mut. *cana:* flowering spikes of the two types into which each generation splits; on the left the *Lamarckiana* type, on the right the parental type, showing the thin buds and the bent tips of the calyx; the difference in height of the 2 spikes is the same as the mean difference in height of the 2 groups on the bed; third generation of mut. *cana* no. 3, photographed July 22, 1914.

more slender than in *O. Lamarckiana;* the anthers are thin, provided with a good supply of pollen on stout specimens, but often deficient in this production on the weaker ones, especially in annual cultures.

O. Lamarckiana mut. *cana.*—Among the *cana* mutants from *O. Lamarckiana* only one specimen has been self-fertilized. It arose in 1913 in the fourth guarded generation from a plant introduced into my garden in 1905 from the original field near Hilversum. It was only recognized at the end of July, when it opened its first flowers. It yielded few seeds, which gave rise to 19 seedlings only, all of which flowered in 1914. Of these, 13 exactly duplicated the type of *O. Lamarckiana*, 5 were *cana*, and one was a mutant *nanella*. These figures point to a percentage of 26 per cent *cana*.

O. cana from *lata* no. 1.—From the first mutant of 1906–1907, previously described, I have derived a pedigree family in order to try its constancy and got the following result:



The size of these cultures is given in table I.

TABLE I

Year	Generation	Parent	Offspring		Percentage of cana	Mutants
			Total	Flowering		
1912.....	Second	mutant	31	30	16	.....
1913.....	Third	cana	49	48	24	1 nanella
1913.....	Third	cana	115	65	34	4 nanella
1913.....	Third	Lamarckiana	60	25	0	.....

The offspring of two *cana* individuals of the second generation have been studied separately, as well as those of one specimen of the *Lamarckiana* type. The plants have been under observation through their whole lifetime, so far as space allowed, the numbers of the flowering individuals being given in the column next to that of the totals. The *cana* were all of the same type; the *Lamarckiana* exactly repeated the marks of the original species. Three of the dwarfs have flowered. They all had the marks of ordinary *O. La-*

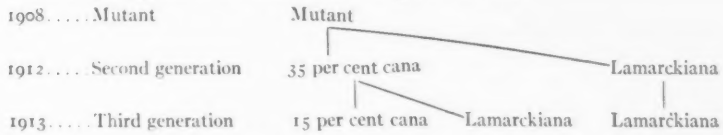
marckiana mut. *nanella* and none of those of *O. cana*. This has been the case in some of the other pedigree cultures of this type, but it should be remarked that in other cases the characters of *O. cana* may combine with the dwarf stature. Such dwarfs have the narrow gray foliage and are easily distinguished from typical *O. nanella* specimens.

The self-fertilized seeds of the *cana* individuals split in both generations into *cana* and *Lamarckiana*, just as *O. scintillans* splits into *scintillans* and *Lamarckiana*. The proportions 16–24–34 per cent with a mean of 25 per cent seem to indicate a splitting into nearly equal parts, with a loss on the side of the weaker form. The same deviation from equality will be seen in almost all the figures of this article, and the same explanation must be considered as applying to all of them. It is almost always the new type which is in the minority.[6]

The seeds of the *Lamarckiana*-like individuals do not give rise to a splitting of this kind, keeping true to their parent form. The same fact recurs in all the pedigrees to be mentioned later on, and for all the new dimorphic types. It may be taken to be the rule, therefore, although the trials have been only one or two in each instance. It agrees fully with the behavior of the analogous splitting products of *O. scintillans*.

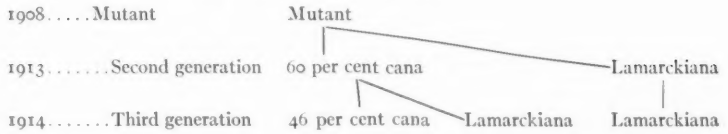
O. cana from *lata* nos. 2 and 3.—In a culture of about 600 seedlings of *O. lata*, 4 mutants of the *cana* type arose in 1908. The *lata* strains had been derived from some annual mutants which had been produced by my *O. Lamarckiana* in 1905, and described in my *Gruppenweise Artbildung* (p. 247). From these mutants a second generation was cultivated in 1907, and fertilized by the pollen of *Lamarckiana*-like individuals of the same culture. Their seeds yielded the two *cana* mutants to be described here, and two others, from the seed of which only one generation has been studied.

The pedigree of mutant no. 2 is given below:



[6] Excepting the case of biennials; see later statement.

That of mutant no. 3 was as follows:



It is easily seen that they agree almost exactly with the pedigree of mutant no. 1, and simply give further proofs of the conclusions drawn from this. The size of the two cultures is given in table II.

TABLE II

Year	Generation	Parent	Offspring		Percentage of cana	Mutants
			Total	Flowering		
	A					
1908.....	mutant no. 2	.....	.....	.....	.....	.....
1912.....	Second	mutant	17	16	35	2 nanella
1913.....	Third	cana	55	45	15	2 nanella 2 new
1913.....	Third	Lamarckiana	60	25	0	.....
	B					
1908.....	mutant no. 3	.....	.....	.....	.....	.....
1913.....	Second	mutant	30	30	60	1 lata, 3 nanella
1914.....	Third	cana	57	56	46	3 nanella
1914.....	Third	Lamarckiana	60	25	0	.....

In each case the self-fertilized seeds of only one *cana* were studied, besides those of the mutants, and also those of only one atavist of the *Lamarckiana* type. The progeny of the latter proved to be uniform and like the parent, about one-half of the plants being studied in the flowering condition and the remainder in the stage of large rosettes of radical leaves in July. The *lata* mutant has flowered, as have the majority of the dwarfs. Two mutants of a new type arose, which will have to be described in another paper. They resembled *O. rubrinervis*, but lacked the characteristic brittleness of the stems of this form.

The second generation of mutant no. 3 has been the most vigorous one of all my annual cultures of *O. cana*. It was grown, moreover, under exceptionally favorable conditions. For this reason it has been chosen for making a series of crosses, which will be dealt with at the end of this article. The fact that, in this case,

the percentage figures come so much nearer to equality of the two types than in the other cases is probably owing to this striking vigor of the race. The means are 25 per cent *cana* for no. 1 and no. 2, but 53 per cent *cana* for no. 3. The proportion of mutants among the seedlings of the *cana* individuals is 18 in 350, or about 5 per cent.

O. cana from *lata* nos. 4 and 5.—As previously mentioned, the progeny of two further mutants of the same origin have been studied. The offspring of one of them embraced only 15 individuals, of which 13 have flowered. There were 3 *cana*, 2 mutants (one *oblonga* and one of the same new type as in no. 2), the 10 remaining plants being externally like *O. Lamarckiana*. The second original mutant yielded only 11 offspring, among which 7 were *cana*, one *Lamarckiana*, and 3 *oblonga*. Although these cultures do not justify the calculation of percentage figures, they evidently support the conclusions drawn from the three former ones, and argue for the conception that this form of splitting is typical for *O. cana*.

INFLUENCE OF CULTURE ON PERCENTAGE FIGURES.—I have shown[7] that the percentage figures for the splitting of *O. scintillans* in the succeeding generations may differ for different families. Sometimes it is only 15 per cent, more often it varies between 34 and 39 per cent, and in rare cases it reaches 69–93 per cent. Subsequent experiences have suggested the idea that these differences are due mainly to outward conditions or to the method of cultivation, and that favorable influences must increase the percentage of individuals with the type of *scintillans* and diminish the percentage of *Lamarckiana*-like specimens.

The self-fertilized seeds of the *cana* individuals previously mentioned have given the following percentages of specimens with the *cana* type: 15 and 16 per cent, 24–34 and 35 per cent, and 46 and 60 per cent, the two latter being found in a culture which excelled the others in vigor. Evidently these figures run parallel to those of *scintillans* and the variability must have the same cause in both cases.

In order to ascertain the nature of this cause I have tried to answer two questions, namely: (1) are the percentage figures

[7] The mutation theory. Chicago. 1909. pp. 388–391.

different on different parts of the main spike of a plant and on different branches; and (2) are they different for annuals and biennials, provided that the individual strength is in both cases as great as possible? The following experiments will show that the first question is to be answered in the negative, but the second in the affirmative; or in other words, the percentage figures depend upon individual vigor of the plants, and this between the widest possible limits.

The second generation of mutant no. 3, cultivated in 1913, was the most vigorous of all my annual cultures, as already mentioned. I chose for my experiment, therefore, the strongest individual of this group, having the largest supply of pollen in its anthers, and fertilized its flowers on the main spike and on a lateral branch in small bags, each with its own pollen. At the time of harvest I separated the fruits in groups of 10 each; there were 4 of these groups on the main spike and 2 on the branch. In the spring of the following year (1914) I sowed the seeds of these 6 lots separately. I counted the seedlings in the stage shown in fig. 1 without transplanting them. The *cana* were easily distinguished from the *Lamarckiana* by their narrower leaves and gray color. There were a number of dwarfs, which combined with this character those of *cana* and will be called *cana-nanella*. I have planted them out after finishing the countings and found them true dwarfs of the *cana* type. About a dozen of them flowered as annuals, and some flowered the following year as biennials. The result of the countings is given in table III.

TABLE III

	Number of seedlings	Percentage of cana	Percentage of cana-nanella	Percentage together
A, main spike				
base	57	40	5	45
second group	114	30	4	34
third group	121	31	4	35
top	129	35	5	40
B, lateral branch				
base	95	39	4	43
top	94	31	11	42

The means for the whole plant are 34, 6, and 40 per cent. It is easily seen that the deviations from the means fall within the

limits of ordinary chance, although all the seeds from the 10 capsules of each group have been sown. Thus it is clear that the first and the last fruits of a spike and those of a side branch may give the same percentage figures of specimens of the parental type. Moreover, the mean value is not essentially different from the means of the pedigrees, as just given, which was 33 per cent. We may conclude, therefore, that the mean percentage for all my annual cultures is about 30–40.

In order to compare the influence of biennial culture upon this figure, I chose three healthy and very vigorous rosettes of 1913 and kept them through the winter under glass. They had been reared from seeds of a biennial mutant belonging to the group of *cana* mutants from *lata*, from which pedigrees no. 2 and no. 3 were derived; but this special culture stayed in the rosette condition during 1913. In 1914 three plants of the *cana* type became very vigorous, reaching about double the height of the annual plants and growing up to more than 2.5 m. Their stems also had twice the thickness of the others, the foliage and flower spikes were very dense, and the flowers much stouter. Every evening 4 or 5 flowers opened on the same spike, against 1 or 2 in ordinary cases. The number of fruits on a spike was 60–80, whereas 40 fruits, as just given, is a high value for an annual plant. All of these fruits were self-pollinated in little bags, and yielded 1–1.3 cc. of seeds from 10 fruits, whereas the annuals give only 0.5–0.9 cc. of seeds in 10 fruits. We may summarize these details by saying that my biennial specimens of 1914 were about twice as vigorous as the very best of all my annual cultures.

TABLE IV

Plant	Fruits	Seeds in cc.	Seedlings	Percentage of cana
No. 1.....	63	6.6	590	96
No. 2.....	79	10.0	1099	93
No. 3.....	64	6.3	277	97

All the seeds were sown in boxes in 1915 and the seedlings counted out, without being transplanted, in the stage corresponding to fig. 1, when the differentiating marks were very sharp. The three plants gave the results shown in table IV.

The remaining 4–7 and 3 per cent were mostly of the *Lamarckiana* type, with some mutants belonging to *albida*, *oblonga*, and *nanella*. I had saved the fruits and their seeds in 7 or 8 groups, beginning at the base of the spike, and sown the seeds separately. But, just as in the previous case, there were no appreciable differences in the percentage figures between the higher and the lower groups.

The main result is that the percentage of specimens of the *cana* type, which runs 15–60 per cent on annual individuals, may increase to 93–97 per cent on very vigorous biennial plants. It is thus clearly seen to be dependent upon the method of cultivation. Obviously this rule may be applied to the percentages of *O. scintillans*, as previously discussed, and to those of *O. pallescens* and the other new dimorphic mutants to be described in this article.

Oenothera Lamarckiana mut. *pallescens* (fig. 3).—Among all the mutants which arose in my garden from *O. Lamarckiana*, this form most closely resembles the parent type. In early stages the rosettes are the same, and in springtime, when still in the boxes, I have not as yet succeeded in distinguishing them. It is not until about 6 weeks after planting out on the beds that the differentiating marks begin to show (fig. 4). In the middle of June the leaves are clearly shorter, and the blade is set off from the narrowly-winged petiole by a sharp indentation. This character causes the rosettes to be more open because the petioles hardly touch one another.

This spatulate form of the leaves remains, for a long time, the best mark of the race; but when the stem grows up, the whole plant is much more slender than the parent form (fig. 3). The stem is thin and low; in July, when the first flowers open, it often reaches only 75 cm., when the corresponding specimens of *Lamarckiana* are already 1 m. and more in height. After a time, however, this difference disappears, since the spike is more elongated. It is less dense than in *Lamarckiana;* the bracts are much shorter and strikingly broader; the flower buds are large and conical, the flowers somewhat smaller, although still larger than those of *O. biennis;* the pollen is abundant and the fruits are short and thick, containing a good supply of seed. The foliage is of the same green

FIG. 3.—*Oenothera Lamarckiana* mut. *pallescens:* the 2 types into which each generation splits; to the left the *Lamarckiana* type; to the right the parental type; August 1914.

color as in the parent form, but much more crinkled and uneven, not as gray as in *O. cana*, nor as hairy as in this form.

The impossibility of distinguishing the young plants before planting out evidently makes this mutant less fit for the determination of splitting percentages, because the sorting and counting has to be done on the beds. In my experiments I have always counted the individuals of the two types at the beginning of the flowering period, since at this time the limits between the two groups are the most sharp.

FIG. 4.—*Oenothera Lamarckiana* mut. *pallescens:* 3 typical leaves of the rosette of radical leaves; June 16, 1914.

Moreover, this similarity between the mutant and the parent species must diminish the chances of discovering mutant specimens of the new type. This is probably the reason why it was not observed before 1911. Since that year new mutants of the *pallescens* type have more than once arisen from *O. Lamarckiana* and from some of its derivatives, especially in 1914. All of these mutants exactly resembled the first one in their whole structure and in all their marks.

I have made pedigree cultures of the offspring of my first three mutants. These arose from seed of the same parent plant of 1909, which belonged to the second generation of a guarded strain of *O. Lamarckiana*, derived from a rosette collected in 1905 in the original field near Hilversum. One part of this seed was sown in 1910 and yielded, among about 500 specimens, 1 *pallescens*, together with 1 *rubrinervis*, 3 *oblonga*, 2 *lata*, 1 *scintillans*, 1 *nanella*, the

specimen of *O. Lamarckiana* mut. *semigigas* described by STOMPS,[8] and a narrow leaved specimen, exactly resembling the type described and figured by GAGER[9] for a derivative of *O. biennis*. The specimen of *pallescens* was discovered by chance, since almost none but mutants and a number of doubtful specimens had been planted out; it occurred among the latter and was distinguished as a new type only at the time of flowering. Thereupon, another part of the same sample of seeds was sown in 1911 and yielded two more specimens of *pallescens*, among about 250 flowering individuals.

The self-fertilized seeds of these three mutants gave rise to a mixed progeny, the smaller half of which resembled the parent, whereas the remainder presented the type of *O. Lamarckiana*, duplicating this in all of its special marks and during all the stages of their development. In the following description I will, therefore, indicate them simply as *Lamarckiana*, without discussing the question whether some internal characters might perhaps be different. But externally there is no difference; moreover, the progeny of this derivative *Lamarckiana* behaves exactly like that of normal ones. This splitting into these two types has repeated itself in the following generations and in all of the cases investigated.

Moreover, the *pallescens* seems to be mutable to a higher degree than *O. Lamarckiana* itself; for, although my cultures have been necessarily small, the number of mutants is very striking, reaching 20 among about 500 specimens, or 4 per cent. From the first three mutants I have derived three pedigree families, which I will now briefly describe.

PEDIGREE OF MUT. *pallescens* NO. 1

1910	Mutant	Mutant			
1911, 1913	Second generation	42 per cent pallescens	Lamarckiana	1 mutant	rubrinervis
1913	Third generation	23–43 per cent pallescens	Lamarckiana	Lamarckiana	rubrinervis
1914	Fourth generation	24 per cent pallescens	Lamarckiana	Lamarckiana	
1915	Fifth generation	38 per cent pallescens	Lamarckiana		

[8] STOMPS, THEO. J., Die Entstehung von *Oenothera gigas* DeVries. Ber. Deutsch. Bot. Gesells. **30**:406. 1912.

[9] GAGER, STUART C., Cryptomeric inheritance in *Onagra*. Contrib. Brooklyn Bot. Garden no. 3, Bull. Torr. Bot. Club **38**: 461-471. *figs. 2.* 1911.

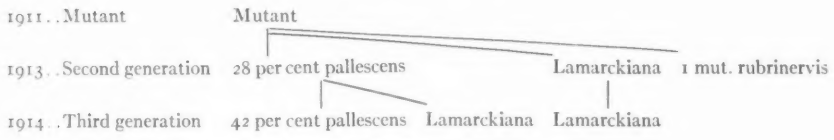
The size of these cultures is given in table V.

TABLE V

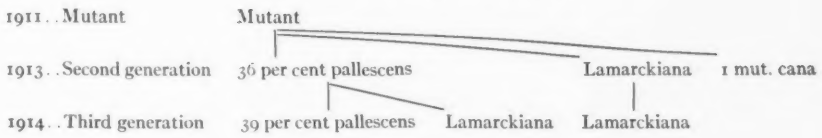
Year	Generation	Parent	Total offspring	Flowering individuals	Percentage of pallescens	Mutants
1911.....	Second	mutant	129	6	.....	1 rubrinervis
1913.....	Second	mutant	40	40	42	1 liquida
1913.....	Third	pallescens	69	69	23	.....
"	"	pallescens	65	65	43	1 nanella, 1 cana
"	"	Lamarckiana	90	50	0	1 scintillans, 1 lata, 1 albida
"	"	Lamarckiana	56	50	0	.....
"	"	rubrinervis	70	25	0	.....
1914.....	Fourth	pallescens	55	53	24	1 nanella
"	"	Lamarckiana	58	25	0	.....
"	"	Lamarckiana	80	25	0	.....
1915.....	Fifth	pallescens	60	25	38	.....

The offspring of the 4 specimens of *Lamarckiana* had this uniform type, in the flowering specimens as well as in the other ones. These were examined in June and July when in large rosettes of radical leaves. The offspring of the mutant *rubrinervis* was also uniform and exactly resembled the race of this name in all its marks, and especially in the brittleness of its stems. The offspring of the original mutant, cultivated in 1911, embraced 129 plants, only 6 of which have flowered, the others having been destroyed before the significance of the culture had been realized. Among these 6, 2 were *Lamarckiana*, 3 *pallescens*, and 1 mut. *rubrinervis*. Their offspring were studied in 1913, as given in table V. Among the mutants the *rubrinervis*, *liquida*, *scintillans*, *lata*, and *cana*, as well as one *nanella*, flowered and proved their identity with the races of these names at that period.

PEDIGREE OF MUT. *pallescens* NO. 2



PEDIGREE OF MUT. *pallescens* NO. 3



The size of these cultures is given in table VI.

TABLE VI

Year	Generation	Parent	Total offspring	Flowering individuals	Percentage of pallescens	Mutants
A						
1911	mutant no. 1					
1913	Second	mutant	25	25	28	1 rubrinervis
1914	Third	pallescens	57	57	42	5 nanella
1914	Third	Lamarckiana	60	25	0	
B						
1911	mutant no. 2					
1913	Second	mutant	25	25	36	1 cana
1914	Third	pallescens	25	25	39	1 lata, 3 nanella, 1 cana
1914	Third	Lamarckiana	65	25	0	

Among the mutants the *rubrinervis*, both *cana*, one *lata*, and some *nanella* have flowered. The individuals of *pallescens* and *Lamarckiana*, which did not flower, were examined in June and July as large rosettes. Most of the flowering specimens were observed during the months of August and September.

The percentage figures of these tables vary from 23 to 43, the means for the 3 families being 33, 35, and 37 per cent, and the total mean being 35 per cent. On account of the evident weakness of the individuals of the *pallescens* type, as compared with their *Lamarckiana*-like sisters, these figures may be assumed to show that the splitting into two main types took place in about equal parts. The splitting is constantly repeated from the *pallescens* specimens, but the progeny of the *Lamarckiana* type retain this type uniformly.

I have made only one cross in these families, and that in order to ascertain the properties of the pollen of the *pallescens* individuals. I placed this pollen on the stigma of some flowers of

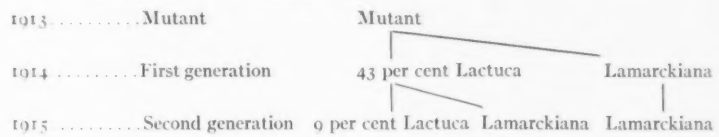
Lamarckiana in 1913, and got from the seeds a uniform generation of 60 flowering individuals, all of which proved to be *Lamarckiana*. I conclude from this fact that the pollen of the *pallescens* plants does not transmit the characters of the race, exactly as in *O. scintillans* and *O. cana*.

O. Lamarckiana lata mut. *Lactuca* (fig. 5, *C*).—In the summer of 1913 I found, in a race of *O. lata* which had been fertilized in the previous generations (1905 and 1907) by *O. Lamarckiana*, a weak plant which seemed to be new to me, but showed evident signs of affinity with the inconstant types of *O. cana* and *O. pallescens* as previously described. It was fertilized, therefore, purely by its own pollen. It yielded 0.8 cc. of seeds, which were sown in 1914 and gave rise to 65 plants, one of which was a mutant of the ordinary type of *O. nanella*, and subjected to the same bacterial disease which so often deforms the dwarfs of my race. Among the others, two types were represented in about equal numbers. One type was exactly like normal *Lamarckiana;* it counted 36 individuals, almost all of which have flowered, without showing any recognizable difference from the original wild species. The remaining 28 constituted a new and uniform type, repeating the characters of the parent plant of 1913, so far as these had been noticed and recorded. At the time of planting out, in the beginning of May, they very much resembled the compact rosettes of *O. nanella*, but without any signs of the disease. About the middle of June, when the rosettes of the type of *Lamarckiana* were growing very fast, those of the new

FIG. 5.—Typical radical leaves of *A*, *Oenothera Lamarckiana* mut. *liquida; B*, mut. *cana; C*, mut. *Lactuca;* June 1914.

type remained small, their leaves reaching only about half the length and half the breadth of those of their sisters (7×3 cm. against 14×5 cm.). Their blades were sharply set off from the winged petioles (fig. 5, *C*), and thereby they much resembled those of *O. pallescens* (fig. 4). This resemblance continued during the development of the stem and the flower spikes; but even as the rosettes were smaller and more densely leaved, the stems were lower and weaker and less branched. The leaves were narrower and folded along the middle vein, instead of being broad and flattened, as in *O. pallescens*. The flower buds were as thick and as large as those of this species, and the flowers also reached the same size, the petals having a length of 4 cm. During the flowering period the differences from *O. pallescens* grew gradually less, and at the end, in September, the new type seemed to be only a weak form of this latter, reaching a less height and being almost unbranched. Artificial self-fertilization has been difficult, since in many flowers the pollen was in an imperfect condition. Four specimens yielded a sufficient harvest (0.5–1 cc.). The sister plants of the *Lamarckiana* type showed an abundance of seed, exactly as the *Lamarckiana* of pure origin does.

The next year (1915) I sowed the seeds of one specimen of the parental type and of two of the type of *Lamarckiana*. The first gave only 44 seedlings, of which 4 were *Lactuca*, one *nanella*, and the others *Lamarckiana*. The two other sowings gave 248 and 283 offspring of their own type, without any *Lactuca* specimens, but with some dwarfs. The number of them was 11, or 4 per cent in the first group, but only one in the latter group. Combining these results we get the following pedigree:



Although only two generations from the seeds of the original mutant have been cultivated, it is evident that this new form behaves exactly like the inconstant races of *O. scintillans*, *O. cana*, and *O. pallescens*. Under favorable conditions it splits into about

equal numbers of the mutant type and of the type of *O. Lamarckiana*. Moreover, a mutant dwarf has been produced.

O. Lamarckiana mut. *liquida* (fig. 5, *A*).—In 1912 and 1913 a new type of mutant was discovered, which came next to *O. scintillans*, had flat and smooth leaves like that form, but the foliage was much broader and lighter green. The individual mutants resembled one another in all respects, save the size of the flowers; they were very slender and had leaves about two-thirds the size of those of *O. Lamarckiana*. The pollen was sometimes abundant, but in other flowers rather scanty.

All in all, I had 6 mutants of this type. One came from seed of *O. Lamarckiana*, but unfortunately it failed to produce good seeds, although the fruits were well developed. Four others arose from *O. lata*×*Lamarckiana*, two in 1912, which also did not yield fertile seeds, and two in 1913. The last one was found in the culture of *O. pallescens* mut. no. 1, and mentioned previously. The seeds of the 3 fertile mutants were sown in 1914 and yielded small cultures, which split up into two types, one repeating the mutant parents in all respects, and the other differing in no visible way from ordinary *O. Lamarckiana*. Besides these there were some mutants which happened to belong to allied types. Table VII gives the size and constitution of these cultures.

TABLE VII

SECOND GENERATION OF *O. liquida*

Mutant 1913 from	Lamarckiana	liquida	Mutant	Total	Percentage of liquida
pallescens	11	6	.....	17	35
lata	61	26	1	88	30
lata	13	8	2	23	35
Total	85	40	3	128	31

In each of these cultures 15 individuals have been allowed to flower, about one-half of these being the *liquida* type and the other half the *Lamarckiana* type. The 3 mutants were *scintillans*, *pallescens*, and *cana*. All 3 have grown vigorously and flowered in August and September; they differed in no respect from the races of the same names.

The percentage of typical individuals in the second generation is about the same as for *O. cana* (25 and 53 per cent), for *O. pallescens* (35 per cent), and for *O. Lactuca* (43 per cent). From this it may be concluded that the 4 races have the same hereditary constitution which, moreover, is the same as in *O. scintillans*.

The next year (1915) I cultivated a third generation of the second mutant of the table (mutant no. 1 from *lata*). The harvest had been small, as in the previous generation, and only 33 seeds germinated. Of these 9 were *liquida*, 1 was *pallescens*, 1 *oblonga*, and the others *Lamarckiana*. All of them have flowered. The percentage for *liquida* was 27, or about the same as in the first generation. Moreover, I have sown for each of the 3 cultures of 1914 the seeds of one or two typical individuals, and also for each of them the seeds of two of the atavistic or *Lamarckiana* type. These 6 last sowings contained 150–300 seedlings each, together 1311, of which 8 were mutants (3 *oblonga*, 4 *lata*, 1 *cana*); the remainder were all of the *Lamarckiana* type, no *liquida* occurring among them. The seedlings of the 4 *liquida* specimens gave the results indicated in table VIII.

TABLE VIII

THIRD GENERATION OF *O.* MUT. *liquida*

Race issued from	Total of seedlings	Percentage of liquida
pallescens	84	25
pallescens	47	28
lata no. 1	80	41
lata no. 2	26	35
Total	237	32

The countings were made in June and July in the boxes in which the seeds had been sown; the plants were all young rosettes with leaves 15 cm. long in the *Lamarckiana* type, and 6–10 cm. long in the *liquida* specimens. The differences were clear and sharp. The table shows that the splitting was almost exactly the same in the third as in the second generation.

Dimorphic races do not seem to be rare among the mutants of *O. Lamarckiana*, and have been observed to spring also from its

hybrids with other species; but the characters are not always as sharp as in the instances described, or the production of seeds is too insufficient for further cultures. Only one case may still be mentioned here. It was a mutant from *O. lata*, discovered in 1914, the self-fertilized seeds of which gave a dimorphic second generation, consisting of 19 plants of the parental type, 47 of the *Lamarckiana* type, besides 2 mut. *oblonga* and 2 mut. *lata*. Almost all of these flowered in 1915. Those of the parental type were strikingly like one another, constituting a wholly new form, with very long, narrow, dark green leaves, the stems low and scarcely branching, the spikes rich with bright flowers like those of *Lamarckiana*, and with a good supply of pollen. The fruits, however, were cylindrical and very thin, containing only a few good seeds. The plants excelled in beauty the species and most of its other mutants, but on account of its slight fertility I do not propose to continue the culture. It may be called *O. superflua*.

O. biennis Chicago mut. *saligna*.—In the second generation of my race of *O. biennis Chicago*[10] I found in 1913, among 870 normal individuals, two specimens of a weaker, narrow-leaved type, which differed sufficiently from the former mutants of this species, namely, from *O. biennis Chicago* mut. *salicifolia* and mut. *salicastrum*,[11] to be considered a new form. One of these new mutants died before flowering, the other yielded, after self-fertilization, a small but sufficient harvest of seeds. One-half of these seeds were sown, but only 17 specimens germinated and grew up into flowering plants. Of these 9 repeated the type of the parent, but 8 returned to the size, vigor, and characters of *O. biennis Chicago*, the grandparent. Although the numbers are very small, they point to a splitting into equal parts, as in the splitting mutants of *O. Lamarckiana* just described.

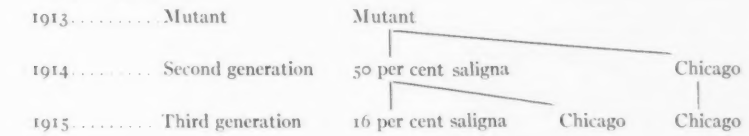
The difference was already evident in March, when the seedlings were only two months old. In June the rosettes were large, but smaller than those of the species, the leaves smooth and narrow. The stems grew up to about one-half the height of their atavistic sisters, and began to flower in September, having a length of 60–120

[10] Gruppenweise Artbildung, pp. 34, 52, etc. 1913.

[11] Gruppenweise Artbildung, p. 304. *figs. 110, 111.*

cm. The spikes were densely flowered, the flowers a little smaller, the fruits thin and long. The production of pollen was insufficient in many flowers, but this may have been the effect of the individuals being transplanted from their boxes to the bed in June, which is relatively late in the season. The seed developed badly and contained only a small percentage of normal grains.

I have sown the seeds of 8 of the 9 specimens with the parental type, and of two of the type of *O. biennis Chicago*. The first split into two types, the second only repeated the form of the parent. The splitting percentages were 11, 12, 13, 15, 15, 17, 18, and 25, with a mean of 16 per cent, but the germination had been very poor, giving only 444 seedlings for the 8 boxes. The progeny of the two specimens of the *Chicago* type was uniform with 252 and 60 seedlings. I counted them in May and June, and left one group of each type to flower. The group from the *saligna* type contained two flowering *saligna*, identical with those of the second generation; that of the atavists 60 flowering plants of the uniform type of *O. biennis Chicago*. From these facts we may conclude that in this race all of the specimens of the parental type give a dimorphic progeny, while the offspring of the plants with an atavistic type remains uniformly so. Resuming the cultures, we get the following pedigree:



The behavior is exactly the same as in the dimorphic races issued from *O. Lamarckiana*.

Crosses of *Oenothera Lamarckiana* mut. *cana*.—As indicated on p. 258 I chose in 1913 the second generation of a *cana* mutant which arose from *O. lata* (no. 3) for a series of crosses. This culture was the most vigorous one of all my annual *cana* families, and its percentage figures seemed to be more normal than in the other cases. The crosses were made in both directions with the pure strains of my species and races described in *Gruppenweise Artbildung*, and the seeds were sown in 1914. This first generation

was counted in July, during the beginning of the flowering period, but about one-half of some of the cultures were kept in the boxes so as to reach only the stage of rosettes at that time. No second generations have been cultivated. I will first describe the results, and afterwards give the necessary details concerning the several cultures.

The main purpose of these crosses was to decide the question whether the special characters of *O. cana* are handed down by the ovules only, as in *O. scintillans* and *O. lata*, or by the pollen also. Table IX gives the result of the crosses with wild species other than *O. Lamarckiana*. Here a splitting occurs into *laeta* and *velutina* or into *dense* and *laxa*, exactly analogous to that produced by *O. Lamarckiana* itself. The only exception is the pollen of *O. biennis*, which does not split; it gives with *O. cana* the same type as with the parent species. The result was very striking on the beds. No specimens of the *cana* type occurred in the cases where this mutant had been the father, whereas such individuals abounded in the results of the reciprocal crosses.

TABLE IX

CROSSES OF *O. cana* WITH OTHER SPECIES

Cross	Percentage of cana	Percentage of laeta	Percentage of velutina	Percentage of mutants
A				
O. cana×O. biennis Chicago	25	11	63	1
O. cana×O. Cockerelli	17	17	63	3
O. cana×O. Hookeri	28	14	58	
O. Hookeri×O. cana	0	4	96	
O. Cockerelli×O. cana	0	54	46	
O. syrticola×O. cana	0	51	49	
O. biennis×O. cana	0	58	42	
		Percentage of densa	Percentage of laxa	
B				
O. biennis Chicago×O. cana	0	24	75	1
O. atrovirens×O. cana	0	36	64	
C				
O. cana×O. biennis	49	51		

In this table, *O. syrticola* Bartlett is the *O. muricata* L. of my *Gruppenweise Artbildung*, and *O. atrovirens* Bartlett has been

described in that book as *O. cruciata* Nutt. The other names are still the same as in my book.

With the same purpose crosses were made with *O. Lamarckiana* and some of its derivatives.

TABLE X

CROSSES OF *O. cana* WITH *O. Lamarckiana* AND ITS MUTANTS

Crosses	Percentage of cana	Percentage of Lamarckiana	Percentage of other forms
O. cana×O. Lamarckiana	42	58	
O. cana×O. nanella	21	71	8 nanella
O. cana×O. rubrinervis	40	25	35 subrobusta
O. Lamarckiana×O. cana	0	98	2 nanella
O. lata×O. cana	1	62	35 lata, 3 mutants
O. nanella×O. cana	1	5	94 nanella
O. oblonga×O. cana	0	82	15 oblonga, 3 mutants
O. rubrinervis×O. cana	0	52	48 subrobusta

The main result is the same. *In all the crosses of both tables the characters of O. cana are handed down through the ovules to a large part of the progeny, but not through the pollen.* The behavior is exactly the same as in *O. scintillans* and *O. lata*. The two specimens of *O. cana* from the crosses of *O. lata* and *O. nanella* must evidently be considered as mutants, that is, as having arisen from the fertilization of mutated sexual cells, since we have seen that such mutations occur from time to time, especially among the seeds of *O. lata*.

Apart from the appearance of plants of the *cana* type, the results of the crosses are, in every case, such as would be expected if *O. Lamarckiana* had been used instead of *O. cana*. In this respect they simply confirm the conclusions given in my book.

Let us now consider in its details the analogy of *O. cana* with the allied forms of *O. scintillans* and *O. lata*. Two cases offer themselves for this consideration. The first one is afforded by the crosses with *O. biennis*. Apart from stray mutants, these produce two types, one of which combines the visible marks of both parents, whereas the other wholly lacks the characters of the mother, but is simply like the hybrid of *O. Lamarckiana* and *O. biennis*, as described in my book. In the first group the combination is such as to make the characters of the mother the most

striking in the hybrids, whereas those of the father, *O. biennis*, have only a less influence on the general type.

In table XI the figures of table IX are combined with the percentages derived from my *Gruppenweise Artbildung*, by taking the means of the two crosses for each case given on pp. 251 and 261.

TABLE XI

O. cana×*O. biennis* COMPARED WITH *O. lata* AND *O. scintillans*

Forms	Percentage of type of mother	Percentage of type of O. Lamarckiana ×O. biennis	Mutants
O. cana×O. biennis	49	51	
O. scintillans×O. biennis	60	36	4
O. lata×O. biennis	57	43	
Mean	55	43	

In this table we see *that the characters of O. cana, even as those of O. scintillans and O. lata, are repeated in about one-half of the progeny, but not in the other half.* We may consider this as the simplest case. In the other crosses the proportions of *cana* are 17, 25, 28, with a mean of 23 per cent in table IX, and 21, 40, 42, mean 34 per cent in table X, and these figures may be assumed to point to a splitting into nearly equal parts with a loss on the side of the weaker form. Exactly the same behavior occurred among the progeny of the self-fertilized individuals of *O. cana*, as we have seen previously.

Let us now compare *O. cana* with the two allied forms in those crosses where the progeny splits into the twin hybrids *O. laeta* and *O. velutina*, as shown in table XII.

The types of *O. laeta* and *O. velutina* have been compared in each case with the twins derived from *O. Lamarckiana* by the same father.[12] The comparison embraced the whole lifetime from the germination in February until the production of the fruits in September. No differences have been observed.

From table XII we see that the splitting percentages are practically the same, whether the pollen is taken from *O. biennis Chicago*, *O. Cockerelli*, or *O. Hookeri*. For this reason I have given

[12] DEVRIES, HUGO, On twin hybrids. BOT. GAZ. **44**:401–407. 1907.

the mean for each group in the last columns of the table, and the reliability of this mean evidently depends strongly on this fact.

TABLE XII

SPLITTING INTO *laeta* AND *velutina*

FORMS	PERCENTAGE OF TYPE OF MOTHER	PERCENTAGE OF LAETA	PERCENTAGE OF VELUTINA	MEANS FOR THE GROUPS		
				Type of mother	laeta	velutina
O. cana×O. b. Chicago	25	11	63			
O. cana×O. Cockerelli	17	17	63	23	14	61
O. cana×O. Hookeri	28	14	58			
O. scintill.×O. b. Chicago	33	32	32			
O. scintill.×O. Cockerelli	21	49	29	30	36	30
O. scintill.×O. Hookeri	35	28	29			
O. lata×O. b. Chicago	21	24	55			
O. lata×O. Cockerelli	21	31	48	27	25	46
O. lata×O. Hookeri	39	18	43			
O. Lamarckiana×O. b. Chicago	.....	19	81			
O. Lamarckiana×O. Cockerelli	.....	11	89	.....	18	82
O. Lamarckiana×O. Hookeri	.....	23	77			
O. nanella×O. b. Chicago	.....	41	59			
O. nanella×O. Cockerelli	.....	38	62	.....	41	59
O. nanella×O. Hookeri	.....	45	55			

Theoretically a splitting into 4 groups of equal size should be expected, namely into *cana-laeta*, *cana-velutina*, *laeta*, and *velutina*.[13] Evidently one of the first two groups is suppressed. This conclusion holds good for *O. cana* just as for *O. scintillans*, but in the case of *O. lata* the fourth group is sometimes visible, a few specimens of the *lata*-like hybrids assuming at the same time the marks of *O. laeta* (about 1 per cent, *Gruppenweise Artbildung*, p. 255), whereas the remainder are clearly *lata-velutina*. It is probable that the same group is suppressed in both the other cases, and for the same reasons, which are as yet unknown. The fact that there are so often more *velutina* than should be expected probably has the same cause as the exuberant occurrence of this form in the crosses of *O. Lamarckiana* (82 per cent). The analogous crosses of *O. nanella*, given in the lower part of the table, show that these

[13] DE VRIES, HUGO, On triple hybrids. BOT. GAZ. 47:1–8. 1909.

diminutions of the *lacta* type may, at least in part, be considered as influenced by neighboring characters. The combination *O. cana nanella* has occurred in many instances during these experiments, either from the crosses of *O. cana* with the dwarfs of my race, or as occasional mutations in other cases. A repetition of my experiments, in which *O. cana nanella* would be chosen for fertilization by the other species or mutants used, would probably give the material to decide these questions.

Putting aside all of these more special considerations, we may conclude that *O. cana behaves in its crosses, as well as after self-fertilization, exactly after the manner of O. scintillans and O. lata.* From this fact and from the cross *Lamarckiana*×*pallescens*, previously mentioned, it seems probable that the other new dimorphic mutants, namely *O. pallescens*, *O. liquida*, and *O. Lactuca*, will follow the same rule if tried in the same way. This rule is evidently independent of the external types of their characters, but must depend upon internal properties of their hereditary qualities.[14]

I will now give briefly the necessary details concerning the crosses mentioned in tables IX and X. As already mentioned, all these crosses were made in 1913 with plants of the same origin. For every cross a single specimen was chosen and some flowers on the lower part of its main spike were castrated. The seeds were sown in February 1914, the seedlings transplanted into boxes, and from these, as a rule, about 25 specimens of each culture were placed in a bed in April and May, giving them a good soil and light exposure and plenty of space to insure a vigorous development until the time of flowering and of fruiting.

O. cana×*O. biennis Chicago.*—A group of 71 specimens, all of which produced high stems and 25 of which have flowered. One was a mutant, combining the gray narrow leaves of *O. cana* with the marks of the stature, foliage, and flowers of *O. lata*. The plants of the type of *O. cana* were exactly like pure *O. cana* at the beginning of the flowering period, in July, when they had reached a height of 70 cm. The remaining plants were like (*O. Lamarckiana*×*O. biennis Chicago*) *laeta* and *velutina*. The reciprocal cross yielded 59 specimens, of which 5 remained in the condition

[14] On these questions see Gruppenweise Artbildung, pp. 268–295. 1913.

of rosettes. Of the remaining 54, about one-half or 25 have flowered, the others reaching this stage approximately at the time when they were pulled up and counted. One plant was a mutant, being a metaclinous *velutina*, just as described in my book on pp. 308–311. The others were *densa* and *laxa*, as should be expected, and agreeing with these types throughout their whole life.

O. cana×*O. Cockerelli*.—A culture of 63 specimens embracing 4 *cana*, 5 *laeta*, and 15 *velutina*, which have flowered, and a large number of rosettes of radical leaves. Two plants were mutants of the type of *O. lata* and one of them has flowered. Neither in the rosette stage nor at the time of flowering have the plants of the *cana* type showed any difference from ordinary *O. cana*, the characters of the father, also of its twin hybrid type, being invisible in them. Such was the case in almost all the beds containing the hybrids whose mother was *cana*, and this made the distinguishing and counting of this type quite easy and sharply defined, and therefore fully reliable. Short narrow leaves of a gray color, a slender spike with long, thin flower buds with nodding tips were everywhere the same distinguishing marks. The *laeta* and *velutina* had the ordinary type of these twins, as produced by *O. Cockerelli*.

The reciprocal cross yielded 19 annual and 13 biennial *laeta*, besides 4 annual and 23 biennial *velutina* of the same type. The annual plants have flowered; the biennials became stout rosettes in July and August.

O. cana×*O. Hookeri*.—Represented by 25 flowering plants, 3 younger ones, and 40 rosettes, and among the flowering individuals 5 *cana*, 5 *laeta*, and 4 *velutina*. The *cana* were like those of the pure type; the *laeta* and *velutina* did not differ from those of the cross *O. Lamarckiana*×*O. Hookeri*, some of the *velutina* being of a yellowish green in such a degree as not to be able to produce a stem. The reciprocal cross yielded only two *laeta*, one of which has flowered, among a culture of 60 specimens. The remainder were *velutina*, 24 flowering plants and 34 rosettes of radical leaves. The types were the same as those in the reciprocal cross.

O. syrticola×*O. cana*.—Represented by 60 specimens of the type of (*O. syrticola*×*Lamarckiana*) *laeta* and *velutina*. Of these 19 *laeta* and 6 *velutina* have flowered, reaching a height of 2 m. in

August. The remaining plants were pulled out as large rosettes in July.

O. atrovirens×*O. cana*.—Represented by 55 plants, among which 8 *densa* and 17 *laxa* have flowered. They were in all respects like the twins of the corresponding cross of *O. Lamarckiana*. Just as in this cross, some specimens had cordate petals and others had linear ones, repeating the *cruciata* type. But on the first plants stray flowers with narrower petals were found, from time to time, indicating a high degree of fluctuability rather than a splitting into two constant and uniform types.

The reciprocal cross yielded only 23 seedlings, 20 of which were yellow and died very early, and the 3 remaining ones were very weak, reaching only a height of 40–60 cm. when they flowered. They had the type of the *gracilis* of the corresponding cross of *O. Lamarckiana*. They were not mentioned in table IX.

O. cana×*O. biennis* L.—Among 70 plants of this culture, one-half had the type of *O. Lamarckiana*×*biennis*, and of these 15 have flowered. The other half were evidently *cana*. Of these, 28 had the stature of typical *O. cana*, but with some marks which indicated an influence of the father. The foliage was less gray, a darker green, with broader bracts, and more dense spikes with smaller flowers than in the other crosses. The stigmas were surrounded by the anthers, insuring natural self-fertilization, as in *O. biennis*. Besides these intermediate types there were 7 dwarfs, which had the gray, narrow, and pointed foliage of *O. cana*, and which in the table have been calculated together with the high specimens of the *cana* type.

The reciprocal cross yielded only *laeta* and *velutina*, together 57 plants, of which about one-half of each type have flowered.

O. cana×*O. Lamarckiana*.—The two types of this culture were exactly the same as in the self-fertilized offspring of the mutant. There were only 19 specimens, of which 6 were *cana*, 11 *Lamarckiana*, and 2 *nanella*. The dwarfs combined the marks of *cana* with those of *nanella* and have been calculated in the table with the *cana* specimens of tall stature.

The same cross had been made in 1907, the seeds being sown in 1913. In this case there were 50 offspring, among which 26

were *cana* and 23 were *Lamarckiana*, while one dwarf occurred. The percentage figures, 52 *cana* and 46 *Lamarckiana*, confirm those of table X.

The reciprocal cross yielded only normal *Lamarckiana*, 60 specimens with one dwarf. Of these 23 have flowered.

O. lata×*O. cana*.—In this case the differences were already very clear at the beginning of June. There were 34 *lata*, 61 *Lamarckiana*, and 3 mutants (one each of *cana*, *nanella*, and *oblonga*). In August 7 *lata* and 9 *Lamarckiana* flowered. They repeated the type of the hybrids of *O. lata* with the parent species.

O. cana×*O. nanella*.—Only 24 seeds germinated. These produced 5 *cana*, 17 *Lamarckiana*, and 2 dwarfs which had the characteristics of *O. cana*. All these plants have flowered.

The reciprocal cross gave 111 plants, of which one was a *cana* of normal stature, 105 were *cana* with the dwarfish stature of *O. nanella*, and 5 had the type of *O. Lamarckiana*. Two of this last type, the normal specimen of *cana*, and 22 dwarfs flowered in August.

O. oblonga×*O. cana*.—Already in June the differences were clear and unmistakable. Among 72 plants 59 were of the *Lamarckiana* type, 11 *oblonga*, 1 *albida*, and 1 *rubrinervis*. Of these, 2 *oblonga* and 12 *Lamarckiana* flowered; most of the others lived through the summer in the condition of large rosettes of radical leaves.

O. cana×*O. rubrinervis*.—Only 20 seeds germinated, and yielded 8 *cana* of the normal type, 5 *Lamarckiana*, and 7 *subrobusta*, all of which have flowered.

The reciprocal cross yielded 59 plants, but in only two types, which were the same as those in the first instance. Of these, 17 *Lamarckiana* and 8 *subrobusta* have flowered.

Summary

1. Besides *O. scintillans*, which splits under ordinary circumstances in every generation into nearly equal groups of plants of the same type and others of the type of *O. Lamarckiana*, I have cultivated pedigree families of 4 other mutants of *O. Lamarckiana* which behave in the same manner. They have been designated

as *O. cana*. *O. pallescens*, *O. Lactuca*, and *O. liquida*. Their *Lamarckiana*-like offspring are constant in their progeny. Besides the two main types, they produce, as a rule, a relatively high percentage of other mutants.

2. The specimens of the parental type are on the average produced in about 40 per cent, the other 60 per cent being *Lamarckiana* with some mutants; but these figures vary with the cultures and with the plants according to their individual strength. They may even increase, on very strong biennials, to 93–97 per cent for the parental type.

3. Dimorphic mutants of this type occur also in allied species of the *biennis* group, as has been discovered by BARTLETT in the case of *O. stenomeres* mut. *lasiopetala* and described in this article for *O. biennis Chicago* mut. *saligna*.

4. In the crosses with older species or with *O. Lamarckiana* and its derivatives, *O. cana* follows exactly the type of the analogous crosses of *O. scintillans* and *O. lata*.

5. In the dimorphic mutants, the special characters are handed down to the next generation through the ovules only. The pollen lacks these characters, and is, so far as investigated, not different from that of pure *O. Lamarckiana*.

6. The dimorphic mutants constitute a group in which the hereditary phenomena are evidently independent of the externally visible characters of the special members of the group, but must be assumed to have the same intrinsic causes in the different cases.

BOTANIC GARDEN
AMSTERDAM

GINKGO AND THE MICROSPORANGIAL MECHANISMS OF THE SEED PLANTS*

EDWARD C. JEFFREY AND R. E. TORREY

(WITH PLATES VII–IX)

The genus *Ginkgo* has long excited interest as the sole survivor of a group which was formerly numerously represented by species and widely distributed geographically. It is the purpose of the present article to show that its microsporangial structures have an important significance from the standpoint of the interpretation of microsporangia of seed plants in general. It will further be indicated in the present investigation that the affinities of the Ginkgoales are not with the Cycadales, as is ordinarily assumed, but with the abietineous subtribe of conifers, which one of us, in numerous articles devoted to the anatomical structure of living and fossil conifers, has attempted to show are the most primitive living representatives of the coniferous stock. Two important memoirs dealing with the genus under discussion have appeared in recent years. SEWARD and GOWAN[1] have given an interesting account of the living *Ginkgo*, together with statements in regard to its extinct predecessors and its botanical affinities. More recently SPRECHER[2] has published an admirable description of the anatomical structures of the various vegetative and reproductive organs in the genus.

The microsporophylls of *Ginkgo* are paired structures opening by means of a stomium along their inner faces. The opening mechanism is a jacket of cells, generally nucleated, with fibrous thickenings extending from the cavity of the mature sporangium to the epidermis. These thickenings are a structural feature of the mechanical layer, and are quite absent in the epidermal layer itself.

* Contribution from the laboratories of Plant Morphology of Harvard University.

[1] SEWARD, A. C., and GOWAN, J., The maiden hair tree (*Ginkgo biloba* L.). Ann. Botany **14**:109–154. *pls. 8–10.* 1900.

[2] SPRECHER, ANDREAS, Le *Ginkgo biloba* L. 8vo. pp. 208. *figs. 205.* Geneva. 1907.

The general distribution and topography of the mechanical tissues of the sporangium may be learned from the somewhat diagrammatic illustration appearing as fig. 17. This figure will be discussed more fully at a later stage. The anatomical details of organization of the microsporangium of *Ginkgo*, as illustrated by photomicrographs, may conveniently be taken up here. Fig. 1 shows a vertical section through one of the microsporangia. At the lower side are spores lying within the sporangial cavity. Transversely in the upper region of the figure runs the termination of one of the fibrovascular bundles of the sporophyll. The bundle is accompanied on its upper side by short transfusion cells, such as are characteristic of the gymnosperms. These appear as reticulated elements. To the right and separated from the transfusion tissue by two elongated unsculptured cells is the bundle proper, with its protoxylem elements uppermost and the larger elements of the metaxylem beneath. Toward the left the bundle as a whole ends in transfusion elements, a situation often present in the gymnosperms. The transfusion cells commonly become imperceptibly merged into the fibrously thickened cells which constitute the mechanical tissues of the sporangium wall. Fig. 2 presents another and less favorable view of the same features.

Fig. 3 reproduces a horizontal section through the petiole of the sporophyll and the two sporangia. Right and left lie groups of spores indicating the position of the spore sacs, while in the center is a fan-shaped mass of tracheids marking the termination of the fibrovascular strands of the sporophyll in a complex of transfusion tracheids. To the right and left of the fan lie cells with elongated nuclei, which mark the position of the two strands of phloem ending in the bases of the sporangial cavities. Fig. 4 reproduces a portion of the right of fig. 3, more highly magnified. The gradual passage of the transfusion elements into the cells which constitute the mechanical system of the sporangium wall can now easily be distinguished. To the extreme right are spores in the cavity of the sporangium, and below these, to the right of the transfusion cells, are to be seen two elongated nuclei belonging to the phloem. Returning now to the radial longitudinal view of the vascular supply of the sporangium, in fig. 5 we see under a somewhat high degree

of magnification transfusion elements above tracheids, which are in turn in intimate contact below with the fibrously thickened mechanical elements of the sporangium. Fig. 6 shows still another view of the tracheids, transfusion and mechanical elements demonstrating their continuity with one another at the termination of the bundle. Below lies a group of spores. Fig. 7 further illustrates, under a considerable degree of magnification, the almost imperceptible transition from the tracheary and transfusion elements of the fibrovascular bundle proper to the reticulated cells which constitute the opening mechanism of the sporangium. To the right in the median horizontal line lie two narrow tracheids. Above and also to the left of these are to be seen transfusion cells with reticulated walls of the type characteristic of *Ginkgo* and certain Abietineae. Inferiorly the tracheids abut immediately upon the reticulated elements of the mechanical or fibrous layer.

Fig. 8 represents the vascular system of the microsporophyll in transverse section. Sporangia lie to the right and left with contained spores. The two vascular strands which are present in the terminal portion of the sporophyll of *Ginkgo* end as such at the base of the sporangia. Directly above the sporangial cavities on either hand are masses of small cells, which constitute the phloem of the vascular bundles. The position of the xylem is less apparent and is marked by crosses lying inside the islands of phloem. As the vicinity of the sporangia is reached the fibrovascular strands turn outward, so that the phloem now lies external to the xylem instead of below it, as in the lower region of the sporophyll. In the median region a large amount of mechanical tissue is present, separating the sporangia and continuous with the ends and sides of the xylem of the strands. Fig. 9 represents a more highly magnified and somewhat oblique view of the situation illustrated in fig. 8. To the right may be seen the small elements of the protoxylem of the bundle of the dextral sporangium. On the left the sinstral strand of xylem is obliquely cut, showing pits and reticulations. Farther to the left it passes imperceptibly into the mechanical elements of the wall of the sporangium.

We may now turn with advantage to the diagrammatic fig. 17. Here the fibrovascular tissues are shown as penetrating the stalk

of the sporophyll. Dorsal to the strand lie transfusion elements distinguishable by their short length and reticulated walls. The tracheids of the bundles in their upward course become ever shorter, and the spiral or scalariform sculpture of the walls is gradually transformed into the reticulations which characterize the transfusion elements in which the bundle ends. The transfusion cells in turn pass by gradual transition into the mechanical elements, which are responsible for the opening of the sporangium at the time of maturity of the spores. It will be seen that the mechanical cells are not confined to the region of the sporangium wall, but pass up into the median horn, which terminates the sporophyll. In some cases the former actually more or less completely surround the secretory space at the apex. In the mature sporangium the mechanical elements extend to the sporangial cavity, being ordinarily separated from it only by a membrane formed from the disorganized tapetum. The mechanical cells form a continuous jacket, and are only interrupted in the longitudinal inner line corresponding to the stomium (not shown). The figure clearly shows that the mechanical elements are not present in the epidermis. The diagrammatic plane of section of the sporangium and sporophyll is necessarily somewhat to one side of the median line of the termination of the corresponding fibrovascular strand, since the latter continues into and is merged in transfusion elements and mechanical cells in the region of the septum between the two spore sacs. For that reason the upward end of the strand does not appear in the field of view. The explanation of the situation is furnished by reference to the horizontal section shown in fig. 3.

It is clear from the descriptions given in the foregoing paragraphs that the fibrovascular bundles of the sporophylls in *Ginkgo* end in transfusion tissue, which in turn passes, often almost imperceptibly (fig. 4), into the mechanical elements of the sporangial wall. It thus is obvious that in this genus the opening mechanism of the sporangium is an adjunct if not a derivative of the fibrovascular system. This situation recalls the interesting observations made by OLIVER[3] over a decade ago in the case of an isolated

[3] OLIVER, F. W., On a vascular sporangium from the Stephanian of Grand' Croix. New Phytol. 1:60–67. *pl.* 1. 1902.

sporangium from the Stephanian of Grand' Croix in France. He notes that in the sporangium in question, which he is inclined to refer to the Botryopterideae, there are 6 islands of tracheary tissue lying in immediate contact with the cavity of the sporangium. A true annulus formed from the outer layer of cells likewise is present, and consequently there can be no case of vascular tissue acting as the mechanism for opening the sporangial cavity at maturity. The author notes the rarity of the phenomenon in vascular plants, where as a rule the tracheary elements stop at an interval from the actual sporogenous elements. He calls attention to the similar phenomenon presented by the tracheids found in relation to the embryo sac in the amentiferous genera *Casuarina*, *Castanea*, and *Corylus*. In a later article[4] OLIVER describes the tracheary investment covering the gametophytes and terminating in the pollen chamber of *Stephanospermum akenoides* and *S. caryoides*. He regards the apparatus in this case as destined to supply the pollen chamber (a constant feature of organization of more ancient gymnospermous seeds) with the water necessary to provide for the fertilizing movements of the antherozoids possessed by these extinct types in common with their nearest modern survivors *Ginkgo* and the Cycadales. In the living forms, however, the tracheary device for supplying fluid to the pollen chamber has disappeared. It is of interest to note in the present connection that in the megasporangium (or seed) of *Ginkgo* the transfusion tissue is present in the peduncle of the organ just as it is in the stalk of the microsporangium, but that it dies out sharply as the megasporangium proper is reached. It is present in abundance in the collar, which lies against the base of the seed. The sporangium in *Ginkgo* would seem, in view of the present observations, to be more tenacious of ancestral characters than is the megasporangium.

It is now desirable to consider certain general features of organization of the wall in the sporangia or microsporangia of the lower vascular plants. Fig. 13 illustrates the structure of a sporangium of *Polypodium vulgare*. Here the opening mechanism is provided

[4] OLIVER, F. W., On the structure and affinities of *Stephanospermum* Brongniart, a genus of fossil gymnospermous seeds. Trans. Linn. Soc. London Bot. II. **6**:361–400. *pls. 41–44.* 1904.

by the annulus, a derivative of the epidermal tissue. A similar situation is presented by the sporangia of other vascular cryptogams. Fig. 14 reproduces the situation for a species of *Selaginella*, one of the Lycopsida. In fig. 15 a microsporangium of *Zamia muricata* is represented. The spore sac is opened by an external annulus, precisely as in the ferns and lycopods. The epidermal character of the opening mechanism is clearly vouched for by the presence of stomata. These are visible on the upper and lower sides of the figure. Noteworthy in this case is the fact that the tracheids of the vascular bundle do not enter into the wall of the sporangium proper, but stop short at its base. Fig. 16 illustrates a surface view of the spore sac much more highly magnified, making clear the position and organization of the stomata. If we compare the condition presented by the sporangia of cycads and vascular cryptogams with that found in *Ginkgo*, a remarkable contrast in the character of the opening mechanism is found. In the lower forms the apparatus for the dehiscence of the spore sacs is known as an annulus and is derived from modified epidermal cells. In the case of *Ginkgo*, on the other hand, no annulus is present, and the opening of the sporangium is provided for by an internal mechanism, obviously an adjunct of the fibrovascular and transfusion tissues, commonly known as the mechanical layer.

It is now convenient to consider the situation in the seed-bearing forms which lie above *Ginkgo* in the scale. The first group to be discussed in this connection is the Coniferales. One of us has pointed out in numerous recent communications that the Abietineae have the strongest claim to a primitive position among the coniferous subtribes. This view is as yet not accepted by the greater number of paleobotanists, but seems to be based on evidence which in the long run is destined to prevail. A most interesting confirmation of the hypothesis of the primitive character of the Abietineae is provided by their microsporangial resemblances to *Ginkgo*. In the first place, the organization of the male cone of *Ginkgo* is similar to that of the Abietineae, since it is composed of sporophylls each bearing two sporangia. One of us has pointed out[5] that the pollen grains of *Ginkgo* possess wings comparable to

[5] JEFFREY, E. C., Spore conditions in hybrids and the mutation hypothesis of DEVRIES. BOT. GAZ. **58**:322–336. *pls. 22–25.* 1914.

those of the Abietineae, and having the same relations to the similar internal structures as do those in *Pinus* or *Abies*. The possession of short shoots and the opposite pitting of the secondary wood, bars of Sanio, etc., as well as a number of other characteristics, likewise definitely indicate a closer degree of relationship between the Abietineae and the Ginkgoales than exists between the latter and any other gymnospermous group. It is accordingly of great interest and importance in the present connection to discover that in so many particulars there is the same striking agreement in the organization of the mechanical apparatus of the microsporangium in the Abietineae and the sole surviving genus *Ginkgo*. One of us has pointed out[6] that on cogent grounds the Abietineae may be divided into two subsidiary groups, the Abieteae and the Pineae. The former are without resin canals in the secondary wood, while the latter are provided with ligneous ducts and have an organization of root, leaf, and cone in contrast to that of similar structures in the Abieteae. A further feature of distinction between the Abieteae and the Pineae is the thick wall of the sporangium in the former. The greater thickness of the wall of the microsporangium of the Abieteae makes it more favorable for study than that of the Pineae. Fig. 12 illustrates the organization of the wall of the sporangium in the genus *Pseudolarix*, which, on account of the absence of tanniniferous contents in the cells of the sporangium wall, is the most suitable for illustration. It is clear that the mechanical tissues in this case, as in *Ginkgo*, extend to the cavity of the sporangium. The outward limit of the opening mechanism in this instance is the exterior of the spore sac and not, as in *Ginkgo*, the layer immediately under the epidermis. The same general situation obtains in all the conifers, apparently, for throughout the group the epidermal cells have the same organization as the mechanical elements. Fig. 10 reproduces a part of a vertical section of a sporangium of *Pseudolarix*. On the left of the figure lie certain cells which have reticulated walls. These are the transfusion elements, and further in toward the axis they are joined with the tracheids of the single fibrovascular bundle of the

[6] JEFFREY, E. C., The comparative anatomy of the Abietineae. Mem. Boston Soc. Nat. Hist. 6:1–37. *pls. 1–7.* 1904.

sporophyll. Toward the right and below in the figure the typical transfusion cells pass directly into elements with a more open reticulation of the wall, the mechanical cells, which constitute the opening mechanism of the sporangium. The jacket of active cells is complete on the free surfaces of the sporangium except where the stomium is present in a terminal position. The septum between the two spore sacs is very largely composed of the fiber cells and the transfusion elements with which they are joined. Fig. 11 reproduces part of a somewhat oblique vertical section of a sporophyll. Here both the sporangia appear at once; toward the right and between them lies the separating partition containing the fibrovascular strand and its associated transfusion elements. Toward the left the transfusion cells can be distinguished, passing directly into elements with much more openly reticulated walls, the mechanical cells. Fig. 18 is a somewhat diagrammatic representation of the anatomical situation in the sporangium of *Pseudolarix*. The tracheary strand comes into the sporophyll and passes outward, giving off a shorter or longer dorsal branch. Abaxially it spreads out into a mass of transfusion elements which are connected with the more coarsely reticulated cells, constituting the mechanical sheath of the microsporangium. Nearly opposite the point of contact of the vascular bundle with the upper wall of the sporangium lies the stomium. The sporophyll ends in a sharp upwardly directed apex, comparable to the less well developed similar structure in *Ginkgo*.

In the Pineae the thin wall of the pollen sac has brought with it such a degree of degeneracy that the topographical relations, seen clearly in the Abietineae, can no longer be discerned. The epidermal layer of the microsporangium is apparently in all cases fibrously thickened, and in this respect differs from the annulus found in the remaining Pteropsida. In the araucarian conifers, which are by many regarded as a primitive subtribe of the Coniferales and more nearly related to the Cordaitales than any other subtribe, significantly enough, the mechanical layer is reduced to the epidermis and has no connection whatever with the fibrovascular system. The same statement is true of the remaining subtribes of the Coniferales other than the Abietineae, which in respect

to their sporangial mechanisms, as in so many other features, show themselves more nearly related to the Ginkgoales and consequently to the Cordaitales. In the Gnetales the opening mechanisms of the sporangia likewise are much simplified and in this respect correspond to the higher subtribes of the Coniferales.

In the highest of the seed-bearing plants, the angiosperms, the microsporangium characteristically opens through the agency of an internal fibrous layer, which has been elaborately described in the monumental memoir of CHATIN on the anatomy of the anther. In both the dicotyledons and monocotyledons this layer is, typically at least, well developed, but does not, as in the conifers, extend into the epidermis. Fig. 19 shows the organization of one of the loculaments of the anther in the common garden tulip (*Tulipa Gesneriana*, hybrid?). Toward the top of the figure lies the stomium, meeting with a corresponding structure belonging to the other loculament of the anther on the same side of the connective. The remainder of the wall shows the mechanical layer strongly developed. In the epidermis stomata can be distinguished. Clearly there is no relation between the mechanical layer and the fibrovascular layer in the connective.

Turning our attention now to the dicotyledons, in fig. 20 we find a diagrammatic representation of a loculament of the anther of *Diervilla florida*, the bush honeysuckle. The stomium does not appear in the figure, but the mechanical or fibrous layer of the anther is clearly to be seen, and, like that in the tulip, it does not extend into the epidermis. In this case, as in the other angiospermous sporangium figured, there is no connection between the mechanical tissues and the fibrovascular bundle of the microsporophyll. On account of the unique development of transfusion tissue of a gymnospermous character in the genus *Casuarina*, it seemed possible that there might be here, if anywhere, some connection between the mechanical tissues of the microsporangium and the fibrovascular bundles. Investigation of the stamens of two species of the genus, however, revealed the same general situation as is found in other instances among the angiosperms; namely, the absence of a relation of continuity between the reticulated cells of the sporangial mechanism and the fibrovascular

strand. It is to be noted that the megasporangial tracheids described by TREUB and BENSON in *Casuarina*, *Castanea*, *Corylus*, etc., are equally without any relation of continuity with the bundle system of the ovule. In general, in the angiosperms the opening of the cavities of the anther takes place by means of a mechanical device, which is not of epidermal origin, and consequently cannot be regarded as an annulus. The structure in question has clearly originated in the deeper tissues of the sporangial wall, and is in all probability derived from the fibrovascular system, as are similar devices in *Ginkgo* and the Abietineae. In the highest seed plants all relation between the opening mechanisms of the anther and the fibrovascular structures have apparently long disappeared.

It is obvious from the discussion of the pertusing devices of sporangia in the preceding pages that there are two main types of opening mechanisms; namely, the annulus, which is clearly of epidermal origin (in the Cycadales actually containing stomata), and, secondly, the fiber layer, occurring in a more or less complete condition from the Ginkgoales upward. This seems equally clearly to have been derived from the fibrovascular structures. Those sporangia which are opened by the instrumentality of an annulus may be appropriately designated *ectokinetic*, while those which owe their dehiscence to the stresses originated by an internal mechanical system, derived from the fibrovascular tissues, may with equal fitness be termed *endokinetic*. If these distinctions be well founded, they obviously supply us with a valuable additional criterion for the course of evolution in the higher plants. The application of these criteria makes it apparently clear that the angiosperms cannot have been derived from the Cycadophyta, a phylogeny wh'ch, moreover, meets many other anatomical difficulties and cannot even be easily reconciled with a reasonable interpretation of the external features of the reproductive parts of the bennettitalean Cycadales and the ranalian angiosperms.

Summary

1. In *Ginkgo* the opening mechanism is clearly an adjunct of the transfusion tissue of the fibrovascular system and is directly continuous with this.

2. A similar condition of relationship between the tracheary tissues and the dehiscing mechanism of the microsporangium is likewise found in the Abietineae among the conifers.

3. In the remaining conifers (and including the araucarians) the sporangial mechanisms are much reduced and no longer have a relation to the vascular bundles of the sporophyll.

4. In the angiosperms the fiber layer of the anther wall is usually well developed and is of internal origin, but has no connection with the fibrovascular system, even in the forms regarded as low.

5. From the Cycadales downward the opening mechanism of the sporangium is of the nature of an annulus and is epidermal in its origin.

6. The facts summarized under the foregoing headings justify the separation of reproductive mechanisms in the vascular plants into two types, the *ectokinetic* and *endokinetic*. The former condition is represented by the annulus and is characteristic of lower forms; the latter is found in the fiber layer, derived from the fibrovascular tissues (particularly modified transfusion elements), and is present characteristically in the microsporangia of existing seed plants (exclusive of the Cycadales).

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EXPLANATION OF PLATES VII–IX

PLATE VII

FIG. 1.—Vertical section through upper part of sporophyll of *Ginkgo biloba*, showing relation of mechanical elements of wall of sporangium to transfusion cells and fibrovascular bundle; ×100.

FIG. 2.—Vertical section of anothersporangium showing the same features; ×150.

FIG. 3.—Horizontal section showing relation of two fibrovascular bundles to transfusion tissue and mechanical elements; ×100.

FIG. 4.—Part of the right of fig. 3 more highly magnified, showing merging of transfusion elements into mechanical elements; ×200.

FIG. 5.—Vertical section of sporangium of *Ginkgo*, showing termination of bundle in transfusion elements and mechanical cells; ×150.

FIG. 6.—Vertical section of sporangium of *Ginkgo*, showing termination of bundle in transfusion elements and mechanical cells; ×250.

PLATE VIII

FIG. 7.—Vertical section of sporangium of *Ginkgo*, showing termination of bundle in transfusion cells and mechanical elements; ×250.

FIG. 8.—Transverse section of sporophyll of *Ginkgo*, showing 2 fibrovascular bundles; ×150.

FIG. 9.—Oblique section of sporophyll of *Ginkgo*, showing on the left transition of bundle into mechanical cells; ×200.

FIG. 10.—Vertical section of sporangium of *Pseudolarix*, showing transition of bundle into transfusion tissue and mechanical cells; ×200.

FIG. 11.—Vertical section of sporophyll of *Pseudolarix*, showing termination of transfusion tissue in mechanical elements of the walls of the sporangium; ×200.

FIG. 12.—Section of sporangium of *Pseudolarix*, showing wall consisting of mechanical cells; ×200.

PLATE IX

FIG. 13.—Sporangium of *Polypodium vulgare* as illustration of sporangial mechanism in a typical fern.

FIG. 14.—Diagrammatic representation of opening mechanism of sporangium of *Selaginella*.

FIG. 15.—Semi-diagrammatic view of sporangium in *Zamia*.

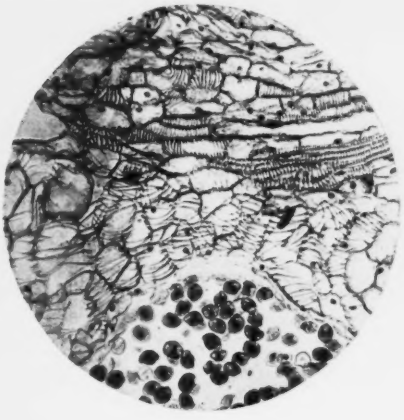
FIG. 16.—Surface view of sporangium in *Zamia* showing stomata enlarged.

FIG. 17.—Semi-diagrammatic view of one of the sporangia of *Ginkgo*, showing relation of fibrovascular tissues to opening mechanism of the sporangium.

FIG. 18.—Semi-diagrammatic illustration of organization of the sporangium in *Pseudolarix*, showing relation of fibrovascular tissues to opening mechanism of sporangium.

FIG. 19.—Transverse section of sporangium of tulip, showing mechanical cells.

FIG. 20.—Transverse section of sporangium of *Diervilla*, showing sporangial mechanism.



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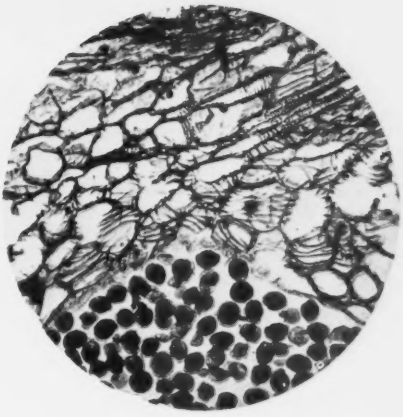

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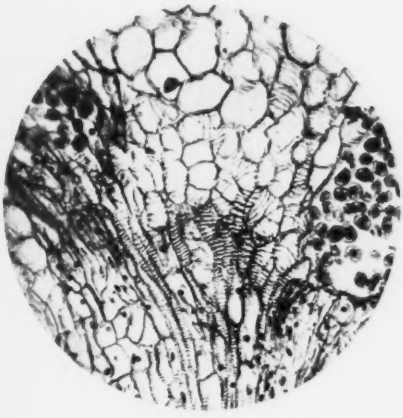

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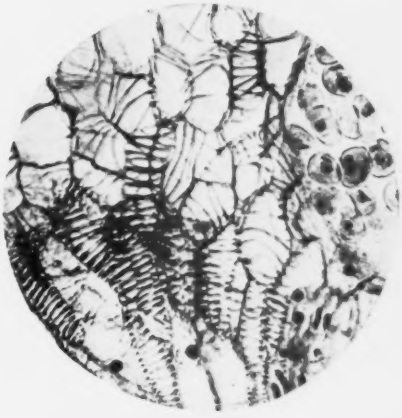

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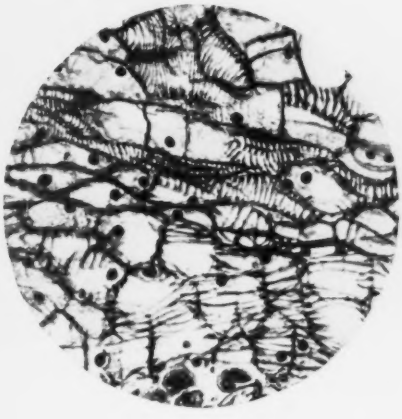

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JEFFREY and TORREY on GINKGO

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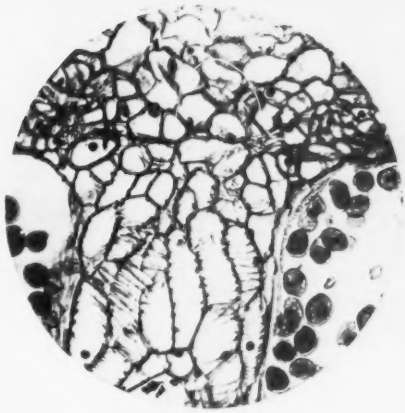

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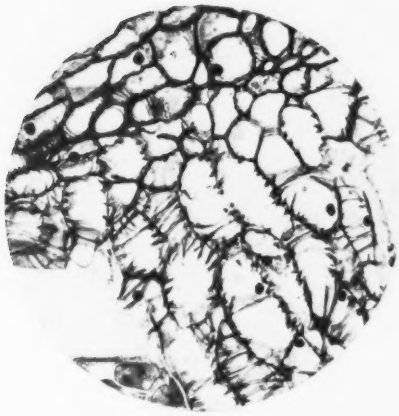

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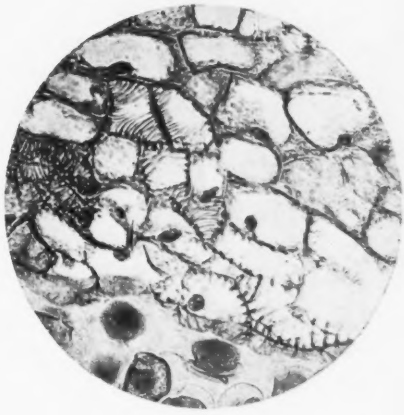

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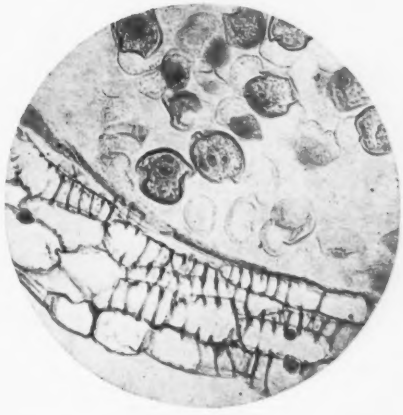

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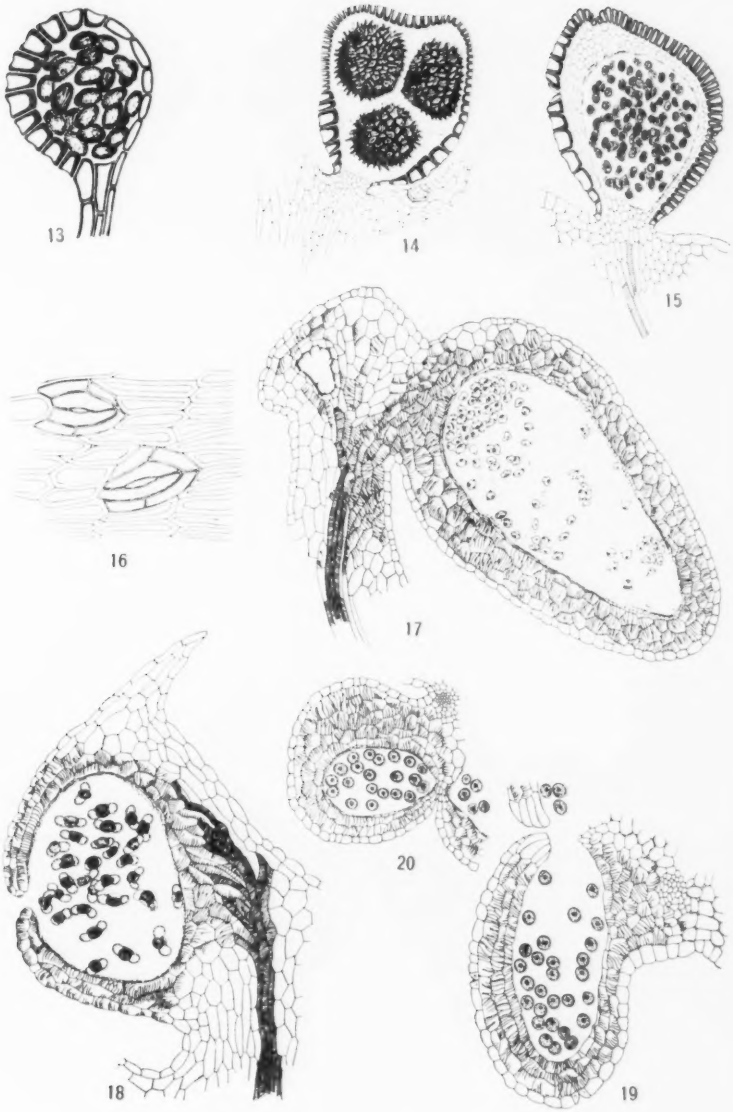
JEFFREY and TORREY on GINKGO



JEFFREY and TORREY on GINKGO

FURTHER EXPERIMENTS ON CORRELATION OF GROWTH IN BRYOPHYLLUM CALYCINUM

JACQUES LOEB

(WITH SEVENTEEN FIGURES)

The following note contains some additional observations on the phenomena of correlation in *Bryophyllum calycinum*. In his first

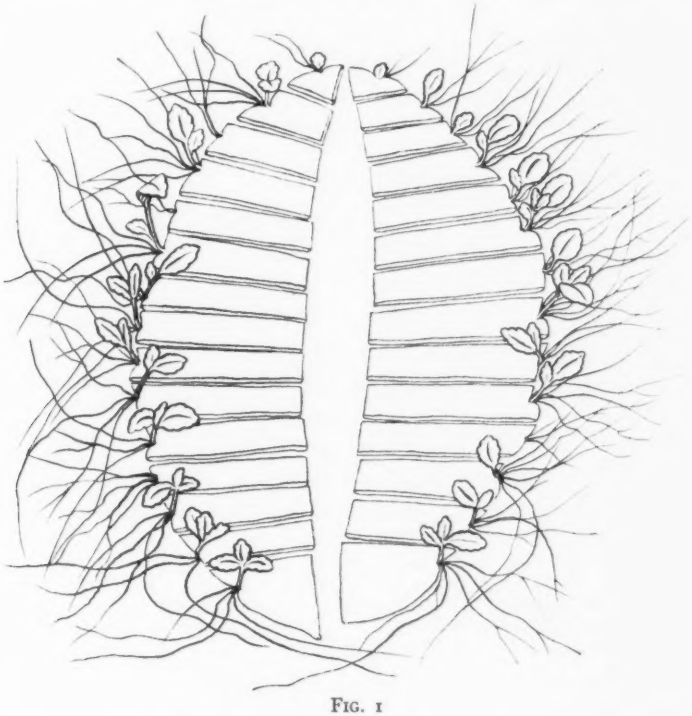
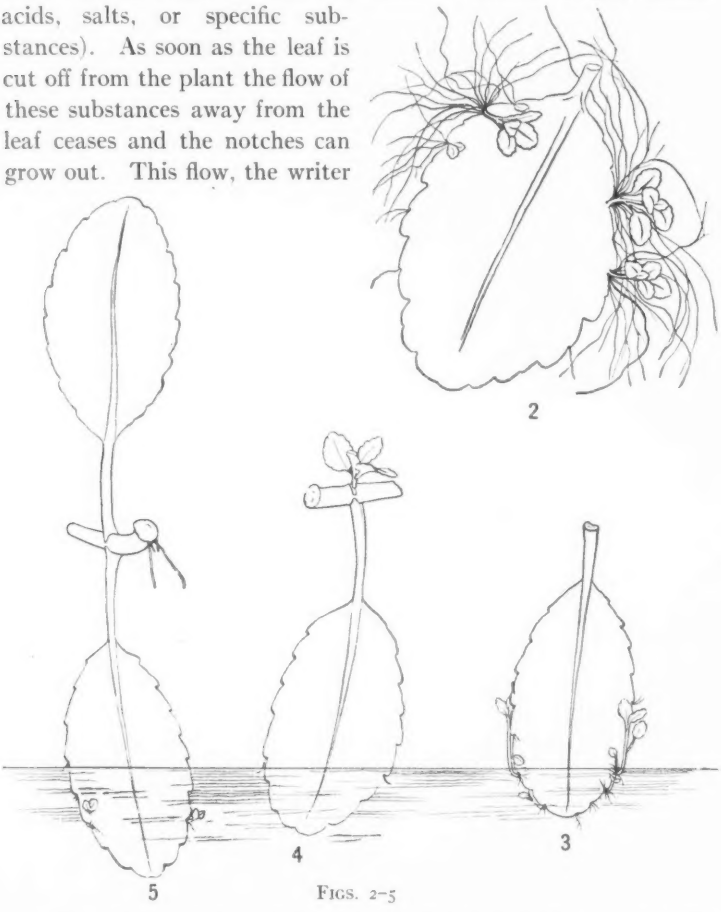


FIG. 1

note[1] the writer had reached the conclusion that a flow of certain substances away from the leaf or its notches prevented roots and shoots growing from these notches, so long as the leaf was connected

[1] LOEB, J., BOT. GAZ. **60**:249–276. *figs. 41.* 1915.

with the normal plant. It is impossible to state at present whether the substances, whose flowing away from the notches prevents these from growing out, are the water or solutes (sugar, amino acids, salts, or specific substances). As soon as the leaf is cut off from the plant the flow of these substances away from the leaf ceases and the notches can grow out. This flow, the writer



FIGS. 2–5

assumes, is caused by a "suction" on the part of the growing tips of the stem or the roots, the "suction" being only a symbol to indicate the direction of the flow.

The experiment illustrated in figs. 1 and 2 never fails. Two leaves from the same node are cut off from the plant and put into

sufficiently large Petri dishes containing some water. One leaf is cut into as many pieces as there are notches. Every notch gives rise to roots and a shoot (fig. 1). The other leaf is left intact and in this leaf only a few notches will grow into roots and shoots (fig. 2), but the growth is much more rapid in these new shoots than

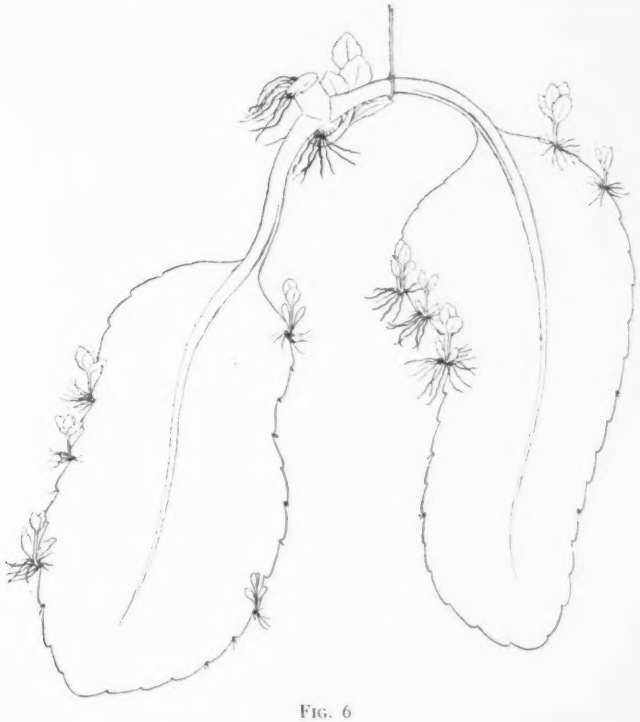


FIG. 6

in those of the other leaf. The explanation is simple enough. In the intact leaf (fig. 2) the notches which by chance happen to grow out first act as if they had a suction effect and caused the current of sap to flow away from the other notches, thus preventing their growth. This illustrates sufficiently the principle of correlation by which the notches of a leaf will not grow out as long as it is connected with a healthy plant. In the latter, the suction of the

growing region of the tips of the stem and the roots causes a flow of substances away from the leaf.

In the previous paper the following experiment was described. Three leaves were submersed with their tips in water. One leaf was completely isolated (fig. 3), the second leaf had a piece of a stem attached (fig. 4), and the third piece had the opposite leaf attached in addition to a piece of stem (fig. 5). The drawing was made 25 days later. The completely isolated leaf (fig. 3) had formed two long shoots, the leaf in fig. 4 had only the two tiny roots, and the submersed leaf in fig. 5 had two short shoots. The experiment finds its explanation on the basis of the observation represented in figs. 1 and 2. In fig. 4 the bud of the stem opposite the leaf grew out before even the notches in the completely isolated leaf of fig. 3 could grow. This growth of the bud on the stem acted as a center of "suction" on the leaf and created a flow away from the notches toward the stem. Even when the growth of this bud is prevented the stem has a suction effect. In fig. 5, where two leaves were left, no shoot would grow out from the stem, and hence shoots could grow out from the immersed leaf, but not as rapidly as in the completely isolated leaf (fig. 3), showing that probably, using the symbol of a "suction," some suction must have been caused by the stem, but not as much as if the opposite leaf had not existed.

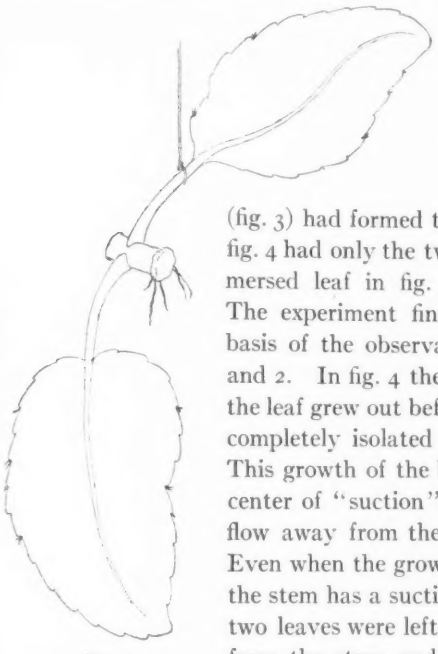


FIG. 7

The writer was anxious to see whether this experiment would not succeed when the whole leaves are suspended in moist air instead of submersing the tips in water. This latter form of the experiment has the drawback that in the leaf with a stem (fig. 4) the growth of the notches in the submersed part is often not entirely

inhibited but only delayed; while if such a leaf is suspended in air the growth of the notches is generally permanently suppressed. Hence if it were possible to repeat the experiment with leaves suspended entirely in air the results should be still more striking.

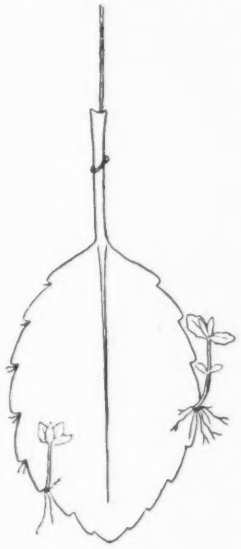


FIG. 8

It was found that if the two leaves connected by their node are large (and probably rich in sap?) they will give rise to new roots and shoots in their notches even if suspended in air. In figs. 6 and 7 two such pairs of leaves of different sizes from the same plant were suspended in moist air. The larger leaves (fig. 6) have each formed 5 shoots in their notches, although also one of the axillary buds of the stem had grown out. This latter growth was not able to inhibit the growth of the notches. In the smaller leaves (fig. 7) no growth had taken place in the notches. The drawing was made 19 days after the commencement of the experiment. The moderate "suction" of the stem sufficed to suppress the growth of the notches in the smaller but not in the larger leaves when suspended in moist air.

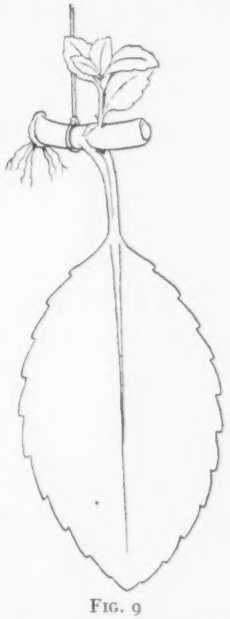


FIG. 9

Figs. 8, 9, and 10 are the replica of the experiment represented in figs. 3, 4, and 5, but with the difference that in figs. 8, 9, and 10 the leaves were entirely in air. The leaves were large and gave a characteristic result. The completely isolated leaf (fig. 8) had formed two large shoots from notches; the leaf of fig. 9 had formed neither roots nor shoots in its notches on account of the complete inhibitory effect of the piece of stem and

its bud. In fig. 10 one shoot had been formed in the lower leaf, which had commenced to grow later than the two shoots in the completely isolated leaf in fig. 8. This drawing was made 5 weeks after the beginning of the experiment. These 3 specimens represent 3 different degrees of "suction" away from the notches of the leaf. In the leaf shown in fig. 9 the suction from the stem was too strong and no notches of the leaf grew. In fig. 10 the suction was less and one notch showed growth, which was less rapid than in fig. 8. In fig. 8, the completely isolated leaf, there was no

FIG. 12

FIG. 11

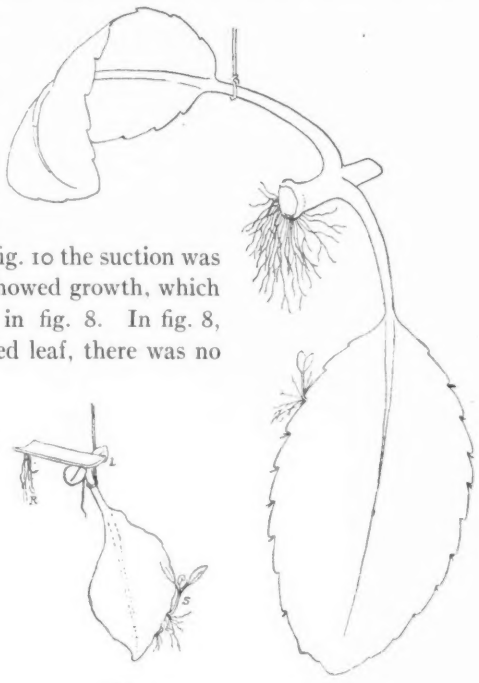


FIG. 10

"suction" away from the leaf and the growth of the notches was most rapid.

A digression is necessary to explain why in fig. 10 only the lower leaf has formed a shoot and not the upper leaf also. The writer is inclined to ascribe the phenomenon chiefly, if not exclusively, to the influence of moisture. The specimens were suspended in a glass trough loosely covered with a glass plate and whose bottom contained a layer of water. The air surrounding the lower leaf was more completely saturated with water vapor than that surrounding

the upper leaf. To settle this question control experiments were made in which both leaves were equally near the water (fig. 6); in this case both leaves formed shoots, while when they were suspended higher up in the trough neither formed roots and shoots. Both leaves also formed roots and shoots when put horizontally into the water. The influence of moisture upon the growth of roots and shoots in the notches was very striking in all these experiments. Thus contact with the wall of the trough, where a condensation of water kept some of the notches moist, would favor the growth of roots and shoots in these notches.

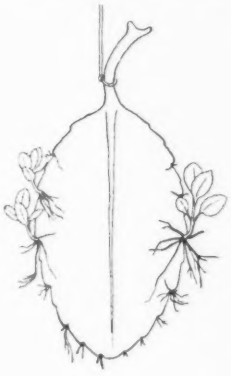


FIG. 13

It has been stated by previous writers that in a completely isolated leaf of *Bryophyllum* the notches grow out because the stalk of the leaf does not form roots. This statement is not strictly correct, as has been stated already in the first article. An example was given in fig. 16, p. 261, where a leaf formed roots and shoots in one notch although roots and a shoot had been formed on the stem, owing to the fact that the piece of the axillary bud was still in contact with the stalk of the leaf. We must assume that in this case the suction from the new growth at the stalk of the leaf was less than if a piece of stem had been there, and this lessened suction permitted one notch of the leaf to grow into a shoot. It occurred to the writer that this assumption might be put to a test. Leaves were prepared being connected by a piece of the cortex of the stem, without the wood (fig. 11), and the behavior of such leaves was compared with the behavior of leaves which were attached to a complete piece of stem (fig. 12). Both sets of leaves were suspended

FIG. 14

in moist air. Leaves of the latter type (fig. 12) never formed shoots in their notches, and at best only a beginning of root formation was noticeable, which never led to roots longer than 1 mm. The bud on the stem opposite the leaf grew out into a vigorous shoot (*S*), and at the lowest point of the callus of the stem, roots (*R*) were formed.

The other type of leaves with only a piece of cortex attached (fig. 11) formed always numerous long roots and quite frequently shoots, while the cortex formed roots (*R*) at the basal end and small leaves (*L*) from the axillary bud of the leaf. The drawing was made after 5 weeks. The growth of the roots and shoots at the cortex did not inhibit the growth of the notches, since in our assumption the suction which the cortex produced was not as strong as if the piece of stem had been complete.

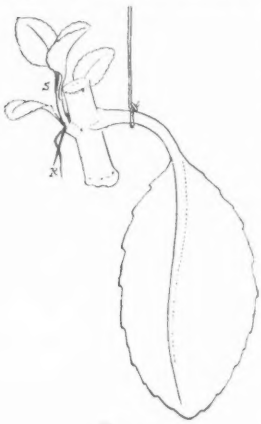


FIG. 15

This furnishes us, therefore, with a method of retarding the velocity of the flow away from the notches of the leaf without interrupting it completely (as in a completely isolated leaf) or without making the flow too strong, as is the case when a whole piece of stem (without the opposite leaf) is attached (as in fig. 12). This difference should find expression in the relative velocity of growth in the notches if the proper experiments were made. Figs. 13, 14, and 15 represent such a series, 3 weeks after the experiment was begun. The leaves were suspended in moist air. The completely isolated leaf (fig. 13) has formed 3 shoots of more than 1 cm. in length and roots of considerable size. The second leaf with a piece of cortex attached (fig. 14) has roots and only one short shoot in the notches, but has a considerable shoot and roots in the cortex. The flow of sap from the leaf to the cortex was not strong enough to completely prevent the growth of the notches, but only to retard it. The third leaf (fig. 15) has a piece of complete stem attached and in this leaf no growth has taken place, and in all probability none

will take place in the notches. Instead a strong shoot (*S*) has been formed from the axillary bud of the leaf which had been removed. The "suction" effect of the complete stem or of the growing bud was strong enough to inhibit the growth in the notches of the leaf completely.

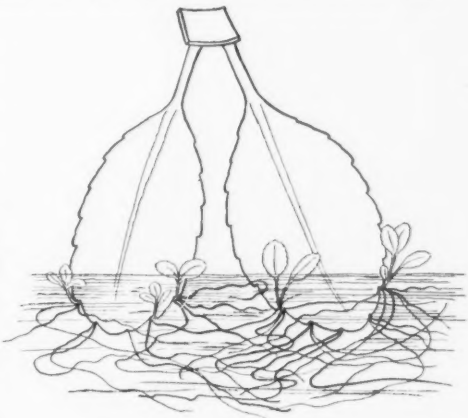


FIG. 16

All these statements can easily be verified. Some variation is met in specimens of the type of fig. 14, inasmuch as very often only the roots will grow out from the notches, while the shoots will not develop beyond tiny beginnings.

In all the experiments we have thus far described the suction effect of the stem inhibited the growth of the notches of the leaf. If the theory be correct that it is only the sap flow to or from a dormant bud which determines whether the latter will grow or continue in a resting condition, the reverse experiment should also be possible; namely, that by accelerating the growth of notches in a leaf it should be possible to inhibit the growth of buds on the stem. From all that has been said this experiment could only meet with success where the suction effect of the stem is moderate. Two leaves of the same node are cut from the plant, the cortex of the piece of stem is cut lengthwise and the wood taken out from the stem (fig. 16). This leaves two leaves connected only by the cortex of the stem (fig. 16). The leaves are placed with their tips under water to induce a rapid growing out of the notches at the tips of the two

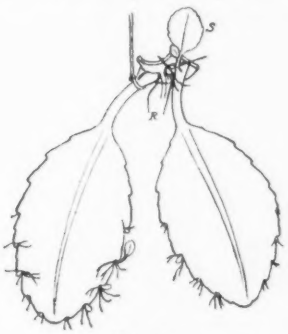


FIG. 17

leaves. Other leaves of the same plant are suspended in moist air (fig. 17). Figs. 16 and 17 were drawn after 22 days. The leaves suspended in air (fig. 17) had formed vigorous roots (*R*) and a shoot (*S*) at the cortex. The leaves themselves had formed, as usual in this case, numerous roots and some tiny shoots. The notches of the leaves suspended in water (fig. 16) had formed very powerful shoots and roots and this inhibited the growth of roots and shoots in the cortex. Needless to say, these experiments were all carried out on many specimens, as were all the experiments reported in this and the previous paper. The experiments show that a vigorous growth in the notches of a leaf can act as a center of "suction" which may prevent the flow of sap to the cortex and thus prevent the growth there, if the suction by the stem, or in this case the cortex, is not too strong.

If the whole piece of the stem is left with its two leaves instead of the cortex alone, the experiment may also succeed, but it is not so reliable since the suction of the stem is greater in this case. If the experiment is made with one leaf and a complete piece of a stem and the leaf is put partly in water, the leaf cannot suppress the formation of the shoot on the opposite side of the leaf, since the suction effect of the stem cannot be overcome by the leaf. But when we have only a piece of cortex instead of a piece of complete stem (with wood), the "suction" power of the cortex alone is less than that of a complete piece of stem, and hence can be suppressed if a vigorous stream of sap to the growing notches of the leaves is started, as is the case in fig. 16.

It is hardly necessary to state once more that the term "suction" effect of a growing notch or bud is used only to illustrate the direction and relative velocity of the flow.

ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH
NEW YORK CITY

THE SEPARATION OF OXIDASE REACTIONS FROM THE CATALASE REACTION

G. B. Reed

(WITH THREE FIGURES)

It is an interesting fact that, with one or two exceptions, the oxidases of plant and animal tissue, even when purified by the best existing methods, still give the catalase reaction, that is, decompose hydrogen peroxide with the evolution of oxygen in its molecular or relatively inactive form. The relation of this catalase action to the physiological activity of the organism is not understood, although several explanations have been advanced.

Loew[1] was the first to isolate a body capable of decomposing hydrogen peroxide but possessing no other enzyme properties. This body he called *catalase*. Many investigations since this time have proved the correctness of Loew's results. Senter[2] prepared from blood a catalase free from haemoglobin or oxidases. Liebermann[3] has shown that aqueous extracts of the mesenteric fat of hogs and rabbits decompose hydrogen peroxide without showing any oxidase reactions. Catalase in every way similar to that isolated by Loew has also been prepared by Wender[4] from yeast, and by Pazzi-Escot[5] from various higher plants.

As a result of his observations, Loew (*loc. cit.*) reached the conclusion that catalase is universally distributed, occurring not only in every organism but in every living cell. He assumed, therefore, that it must have some definite function. Since hydrogen peroxide results from the oxidation of many readily oxidizable substances, he regarded it as at least conceivable that this compound may be produced in the living cell as a result of respiratory processes. The accumulation of such a substance would doubtless

[1] Loew, O., Report no. 68. U.S. Dept. Agric. p. 47. 1901.

[2] Senter, G., Zeit. Physikal. Chem. **44**:257–263. 1903; **51**:673–705. 1905.

[3] Liebermann, L., Pflüger's Archiv. **104**:119–233. 1904.

[4] Wender, Chem. Zeit. **28**:300–301, 322–323. 1904.

[5] Pazzi-Escot, Bull. Soc. Chem. Par. **27**:280–288. 1902.

prove harmful, and its destruction by catalase would not only prevent injury, but the oxygen liberated would be used again in respiration.

USHER and PRIESTLY[6] believe that hydrogen peroxide is formed in relatively large amounts in photosynthetic processes, and that its decomposition by catalase prevents it from reaching a sufficient concentration to bleach the chlorophyll.

On the other hand, SHAFFER[7] considers that the decomposition of the peroxide is of advantage principally in checking oxidation processes, basing his theory on the fact that the oxygen liberated from the decomposition is a poorer oxidizing agent than the hydrogen peroxide. In this connection BATTELLI and STERN[8] state that catalase retards the oxidation of ferrous sulphate in the presence of animal tissue.

There is very little experimental evidence, however, to indicate that hydrogen peroxide is actually produced in living tissue, except under specialized conditions. Moreover, it seems to be not particularly toxic, since the writer has found that wheat, rice, and radish seedlings develop without ill effects in as high concentrations as 0.5–1 per cent. The hypothesis that catalase is of advantage in checking oxidations is also largely invalidated by the observation of BACH and CHODAT[9] that catalase acts only on hydrogen peroxide, and not on organic peroxides or on the oxygenases; for it is these oxygen compounds rather than hydrogen peroxide that are concerned in respiratory oxidations. The writer has found also that while colloidal platinum decomposes hydrogen peroxide, it has no action on the oxygenases. An extract of the outer tissue of potatoes, which exhibits an active oxygenase in its direct action on gum guaiac (free from peroxide), was shaken for some hours with colloidal platinum, but after removing the platinum by filtration[10]

[6] USHER, F. L., and PRIESTLY, J. H., Proc. Roy. Soc. London **77**: 369–376, **78**: 318–327.

[7] SHAFFER, P. A., Amer. Jour. Physiol. **14**: 299–312. 1905.

[8] BATTELLI, F., and STERN, L., Compt. Rend. Acad. Sci. **141**: 916–918. 1904.

[9] BACH, A., and CHODAT, R., Ber. Deutsch. Chem. Gesells. **37**: 1342. 1904.

[10] This sample of colloidal metal could be removed from its solution by passing through a hard filter paper; this is shown by the fact that the filtrate from a watery suspension had no action on hydrogen peroxide.

it was found that the oxygenase was quite as active as before the treatment.

From these observations it appears that the function of catalase in protecting the organism against hydrogen peroxide is extremely limited, if indeed it may be said to exist at all.

Finally, it has been suggested many times, and supported by a considerable body of experimental data, that the action of catalase is associated with the reactions of the oxidases. Although the isolation of catalase has shown that the oxidases are not of necessity concerned in the decomposition of hydrogen peroxide, as was originally supposed, the idea is still held generally that the action of the oxidases is in some manner connected with or dependent upon the catalase reaction.

This association of oxidase action with the decomposition of hydrogen peroxide was suggested at an early date by SCHOENBEIN. He found that plant and animal tissues were usually capable of effecting the decomposition of hydrogen peroxide and activating many oxidation processes. In studying the relative power of various organs of the animal body to break down hydrogen peroxide, SPITZER[11] found them to stand in about the same order in which ABELOUS and BIARNÈS[12] had arranged them in respect to their ability to oxidize salicylic aldehyde. From this correlation SPITZER was led to believe that both processes have the same cause, and he, therefore, used the rate of evolution of oxygen from hydrogen peroxide as a measure of the oxidizing ability of tissues and tissue extracts.

These observations have been extended by LOEVENHART and KASTLE,[13] who have also studied the behavior of certain inorganic catalyzers in this connection. They report a striking parallelism between the rate at which a number of substances activate the oxidation (by hydrogen peroxide) of formic acid or of formic aldehyde, and the rate of hydrogen peroxide in the presence of these substances. They accordingly conclude that catalase action

[11] SPITZER, W., Pflüger's Archiv. **67**:615–656. 1897.

[12] ABELOUS and BIARNÈS, Arch. de Physiol. **8**:311. 1896.

[13] LOEVENHART, A. S., and KASTLE, J. H., Amer. Chem. Jour. **29**:397–437, 563–588. 1903.

and the activation by enzymes of oxidations in the presence of hydrogen peroxide (peroxidase action) are closely correlated and may be referred to a common cause.

A study of the relations existing between the catalase and oxidase actions of colloidal platinum and of certain plant extracts has led the writer to a different conclusion. The present paper contains an account of the experiments with colloidal platinum.

In a previous paper[14] it was pointed out that the *direct* oxidase action (that is, in the absence of peroxides) of colloidal platinum, is dependent upon the amount of oxygen combined with it; that the reaction can be completely inhibited by electrolytic reduction, and again renewed by recharging the platinum with oxygen at an anode. It was also pointed out that the peroxidase action is essentially the same process; namely, in the presence of hydrogen peroxide the metal is kept fully charged with oxygen, while it is at the same time actively giving up oxygen to the substance undergoing oxidation.

The amount of oxygen which could be combined with the platinum electrically was only sufficient to bring about a very small amount of oxidation as compared with that effected by a low concentration of hydrogen peroxide. It was expected, therefore, that the amount of oxygen in combination with the platinum, when it was introduced into a solution of hydrogen peroxide and an oxidizable substance, would have very little effect, either on the rate of reaction or on the amount oxidized. Several measurements proved this to be the case.

Two platinum disks of exactly the same size, 2 cm. in diameter, were cut from the same piece of foil, sealed into glass tubes for convenience in handling, and platinized by the usual method. Care was taken to continue the platinizing for the same length of time with the same current, so that equal amounts of colloidal platinum were deposited on each electrode. These were then attached to opposite poles of a 110-volt circuit delivering one ampere and connected by placing in the opposite arms of a U tube containing dilute salt solution. In this way one electrode was subjected to active oxygen, the other to active hydrogen.

[14] REED, G. B., BOT. GAZ. **62**:53–64. *figs. 4.* 1916.

The peroxidase activity of the two preparations was then compared by removing them from the electrolytic apparatus, washing them quickly by dipping them several times into a considerable volume of distilled water, and placing them separately in flasks, each of which contained 100 cc. of the following mixture: 0.1M formaldehyde, 0.03M NaOH, and approximately 0.1M H_2O_2. The solutions were kept well stirred and at a constant temperature of 18° C. on a water bath. At frequent intervals portions consisting of 2 cc. each were removed and titrated with 0.05M HCl for the amount of formic acid produced from the oxidation of the formaldehyde. The results are indicated in fig. 1, where the curve representing the action of the oxidized platinum is seen to be identical with that which represents the action of the reduced platinum. The points indicated by an ⊙ represent the reaction of oxidized platinum, and the points indicated by a × represent the reaction of reduced platinum. It is thus apparent that the two preparations of platinum are equally effective in this oxidation. Oxidation

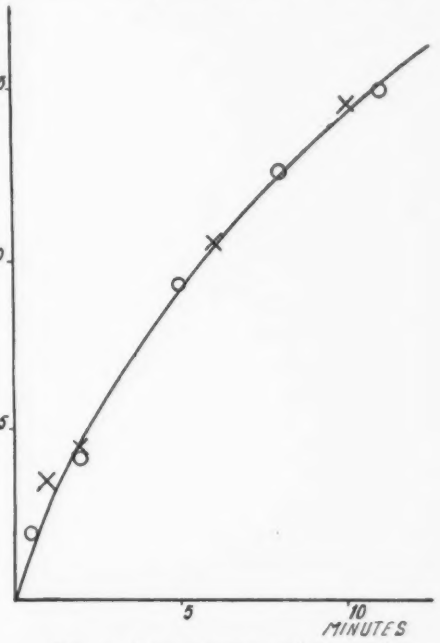


FIG. 1.—Curve showing oxidation of formaldehyde by hydrogen peroxide in presence of colloidal platinum: points indicated by ⊙ are from an experiment in which the platinum had been subjected to active oxygen just previous to placing it in the formaldehyde mixture; points indicated by × are from a second experiment in which the platinum had been previously subjected to active hydrogen; ordinates represent amounts of formic acid formed (expressed as the difference in number of cc. of 0.05M HCl required at the beginning and during the course of the experiment); abscissae represent time in minutes.

(in the presence of hydrogen peroxide) of potassium iodide, pyrogallol, and SPITZER'S reagent was likewise found to be equally catalyzed by platinum, whether it had been treated with active oxygen or with hydrogen.

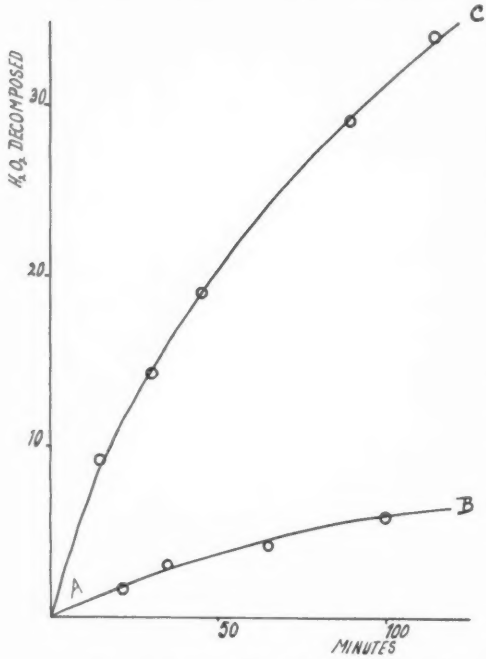


FIG. 2.—Curves showing decomposition of hydrogen peroxide: *AB* shows activity of platinum black which had previously been subjected to active oxygen by using it as an anode; *AC* shows action of platinum black which had previously been subjected to active hydrogen by using it as a cathode; ordinates represent percentage of hydrogen peroxide decomposed; abscissae represent time in minutes.

The action of platinum black in decomposing hydrogen peroxide, however, was greatly modified by its previous treatment. The two electrodes, freshly platinized and subjected to active oxygen and hydrogen as before, were placed separately in flasks, each of which contained 100 cc. of 0.1M hydrogen peroxide, to which a mixture of phosphates (5 cc. of 0.1M NaH_2PO_4 and 10 cc. 0.1M Na_2HPO_4) had been added in order to preserve the neutrality of the solution. As the decomposition of the peroxide proceeded, portions consisting of 2 cc. each were pipetted out, acidified with H_2SO_4 and titrated with potassium permanganate for the amount of hydrogen peroxide left in the solution.[15] The results are shown in fig. 2, where *AB* indicates

[15] Since hydrogen peroxide reduces acidified potassium permanganate quantitatively, the amount of the latter used in a titration is a measure of the unchanged peroxide present in the solution. EULER (Hofmeister's Beiträge 7:1. 1908) has employed this method in the study of catalase.

the rate at which hydrogen peroxide is decomposed by platinum black which had previously been subjected to active oxygen (by using it as an anode), and AC indicates the rate obtained with platinum black which had previously been subjected to active hydrogen (by using it as a cathode); it is apparent that the latter treatment greatly accelerates the catalase action. Thus while electrolytic oxidation or reduction of the platinum apparently has no effect on the peroxidase action of the metal, the catalase action is very greatly modified. That this treatment has no effect on the peroxidase action may be explained by following the oxidation potential of the platinum during the reaction. In a previous paper (*loc. cit.*) it was pointed out that in oxidations by hydrogen peroxide, where colloidal platinum played the part of a peroxidase, the peroxide served to maintain the potential on the catalyzer at a maximum, although the substance undergoing oxidation would tend to pull down the potential. If this be true (since previous treatment with either active hydrogen or oxygen has no effect on the peroxidase action) the same potentials should be

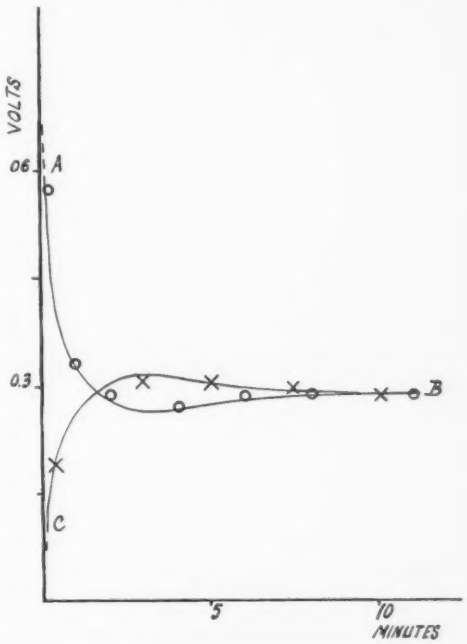


FIG. 3.—Curves of oxidation potential of a platinum cathode in a 0.1M solution of hydrogen peroxide: upper curve AB represents drop in potential on an electrode which had previously been treated with active oxygen by using it as an anode; lower curve CB represents rise in potential on an electrode which had previously been subjected to active hydrogen by using it as a cathode; ordinates represent volts; abscissae, time in minutes.

reached in the peroxide solution, whatever the previous condition of the platinum. The following experiment shows this to be the case.

One of the platinized electrodes which had previously been treated with active oxygen, was connected to the system: $Hg-Hg_2Cl_2-KCl-H_2O_2-Pt$, and the oxidation potential determined.[16] The hydrogen peroxide solution was of the same concentration as used in the previous decomposition experiments (0.1M), and contained a similar solution of phosphates to preserve neutrality. The rate of drop in potential is shown by the curve *AB*, fig. 3. The platinum electrode was then treated with active hydrogen and placed in a similar solution of hydrogen peroxide. In this case the initial potential was low but rapidly increased, as shown by *CB*, fig. 3, to the same equilibrium as reached in the previous case. By comparing these curves it will be apparent that the previous treatment has no effect on the potential assumed by the platinum after it has been a short time in the peroxide.

Although the potential changes on the platinum indicate why previous oxidation or reduction should not alter the peroxidase activity, it makes more complicated the problem of the changes in catalase activity. It is apparent, however, that factors which have no effect on the peroxidase activity do alter the catalase action. In other words, the peroxidase action is quite independent of the rate of hydrogen peroxide decomposition, and the two reactions may be regarded as quite separate. Further experiments by the writer indicate that a similar separation of the oxidase from the catalase reaction may occur in the living cell. These experiments will be discussed in a subsequent paper.

LABORATORY OF PLANT PHYSIOLOGY
HARVARD UNIVERSITY

[16] REED, G. B., BOT. GAZ. **61**:523–527. *figs. 2.* 1916.

SOME FACTORS INFLUENCING NITROGEN FIXATION AND NITRIFICATION[1]

BRUCE WILLIAMS

Progress in the knowledge of soil bacteriological investigations must necessarily depend upon an acquaintance with the individual factors that determine the efficiency of a particular group of soil organisms. Once the relative importance of these factors is determined, the unessential discriminated from those which are of paramount importance, a constructive policy for the promotion of bacterial activity may be announced that will be reflected in an increased fertility of agricultural lands. Investigations on the two general processes, nitrogen fixation and nitrification, have been reported recently from these laboratories.[2] These reports have announced the effects of various organic and inorganic fertilizers in developing certain bacterial floras; the stimulus exerted by cultivation on the two processes just mentioned has been noted; and the comparison of a number of soil types with reference to their bacterial activities was emphasized in the investigations. The results of this work were such as to suggest a number of interesting possibilities to account for unusual conditions that were here and there encountered. Accordingly, an effort has been made to detect some of the influences that are responsible for these conditions and to place certain factors in the relative positions of importance. The data in this paper, which are in every case somewhat preliminary are closely connected with those of the previous publication and are accumulative toward establishing certain contentions which have heretofore been suggested.

The moisture content of a soil with relation to its free nitrogen fixing power is a matter which it would be well to investigate. The rather meager information on this subject has recently been aug-

[1] Paper 44 from Lab. Plant. Path. and Bact. Va. Agric. Exp. Sta.

[2] REED, H. S., and WILLIAMS, BRUCE, Nitrogen fixation and nitrification in various soil types. Va. Agric. Exper. Sta. Tech. Bull. 3. 1915.

mented by an interesting article by LIPMAN and SHARP,[3] giving the point at which maximum fixation is reached in a certain soil and suggesting that there are really two maxima of fixation with reference to moisture content, the one that is most favorable to aerobic bacteria, and the other at which the anaerobic forms most actively flourish. These tests measured nitrogen fixation under the influence of varying percentages of moisture. Of significance also is the effect of various periods of drying on the vitality of the nitrogen fixing flora. The ability of those organisms to withstand long exposure to drying serves somewhat as an index to their activity in arid regions and in more temperate climates after long periods of drought.

It is true also that if any progress is ever to be made in attempts to introduce cultures of free nitrogen fixing organisms, *Azotobacter*, for instance, artificially into soils, the persistence of such species under exposure to drying will be an important determinant in their efficiency. Such phases of the problem as these received attention in the present tests.

Soils which had been in the laboratory 12–18 months, inclosed in glass jars and practically air dried, were employed. All of these soils had been tested originally for this nitrogen fixing power, giving additions of nitrogen ranging from 2.3 to 16.7 mg. per 1 gm. of mannite consumed. *Azotobacter* had been isolated and grown in pure culture from probably 25 of the soils. All of these soils were now taken and 5 gm. inoculations were made into 25 cc. of Ashby's medium in order that qualitative examination might be made for the organism. Examinations made after 4 days revealed *Azotobacter* in only 4 of the soils. Attempts to isolate the organisms from these were unsuccessful, although it is probable that if the efforts had been repeated the organism would finally have been obtained. A number of soils from which it was positively known that *Azotobacter* had been isolated when first brought to the laboratory were then taken, their moisture content brought up to 20 per cent, and the soils kept in the incubator room at 28° C. for 3 weeks. An opportunity was then afforded for the bacterial flora to revivify

[3] LIPMAN, C. B., and SHARP, L. T., Effect of moisture content of a sandy soil on its nitrogen fixing power. BOT. GAZ. 59:402–406. 1915.

itself and regain something of its original status, but similar qualitative tests at the end of 3 weeks showed *Azotobacter* present in only 3 soils, and from one alone was the organism successfully isolated. It appeared from these tests that one at least of the free nitrogen fixing organisms had materially deteriorated through the processes of drying attendant upon 10 months' storage of the soil in the laboratory.

To determine to just what extent drying affected the fixing power of the soils as a whole was the object of the next series of tests. Four soils were selected which had exhibited rather extraordinary fixing powers when first brought from the field, but which had been in the laboratory for 15 months. Fixation tests were made with them, the solution method being employed, which uses 10 gm. of soil in 100 cc. of Ashby's medium, incubated for 21 days, with total nitrogen analysis for increase at the end of that period. The films which formed on two of the flasks were good and gave evidence of the presence of a vigorous culture of *Azotobacter*, but the two remaining ones did not exhibit this characteristic evidence. In table I the efficiency of the soils in question for fixing nitrogen in solution is given.

TABLE I

EFFECT OF DRYING ON THE NITROGEN FIXING POWER OF CERTAIN SOILS

No.	Moisture content after 15 months	Mg. nitrogen fixed per 100 cc. Ashby's medium		
		November 1913	January 1915	Percentage of decrease
1.....	1.8	10.6	7.5	30
2.....	1.3	13.4	8.1	40
3.....	1.0	15.4	11.6	24
4.....	3.8	13.9	7.8	43

The soils lost 24–43 per cent of their original efficiency for fixing nitrogen during the period of 15 months' storage. Whether this falling off in nitrogen fixing power is due particularly to attenuation of aerobic or anaerobic forms is difficult to say, but from evidence previously obtained on the persistence of *Azotobacter* under drying, as previously noted, it is probable that the vitality of this

organism was materially lowered, and to this condition may be referred in large measure the decrease in addition of nitrogen.

A rich garden soil was obtained in the spring of 1915. It was known to have a vigorous *Azotobacter* flora and was examined to determine the effect of short periods of drying on its fixing power. Tests were made at various intervals up to 30 days. The results are recorded in table II.

TABLE II

THE EFFECT OF SHORT PERIODS OF DRYING ON NITROGEN FIXING POWER OF GARDEN SOIL

Percentage of moisture	Date of tests	Mg. nitrogen added by 10 gm. soil in 100 cc. Ashby's medium (after 21 days)
9.1.....	June 7	16.4
6.3.....	" 8	17.0
2.9.....	" 9	14.8
1.5.....	" 18	10.1
1.2.....	July 7	10.1

The gradual decrease in the moisture content of the soil was not reflected in any notable falling off in its nitrogen fixing power until the test made after 10 days' drying. After 30 days, the moisture content remaining stationary, there was no further diminution. Up to this time the nitrogen fixing flora had retained practically 60 per cent of its original efficiency for fixing nitrogen.

The nitrogen fixing flora significantly decreases in its activity under the influence of drying, as the foregoing tests indicate. This deterioration is manifested as early as two weeks after removing the soil from the field and exposing it to the ordinary laboratory conditions of drying. After 15 months, however, a number of soils retained an ability to fix nitrogen that was somewhat surprising, which indicates that some species at least have considerable resistance to drying. A number of qualitative tests for *Azotobacter* in soils kept in storage for 15 months indicate that this organism is more easily attenuated than some other species.

The striking failure of some soils to fix nitrogen lends itself to speculations as to the underlying causes for such a condition. It appears, however, that the nitrogen fixing flora is so intimately

connected with the humus content of a soil that this latter factor is by far the most important influence in connection with the process. The possibility that certain other factors lend a depressing effect has been eliminated to a degree from consideration in this laboratory by results of certain work with reference to toxic conditions of the soil. Whatever may be the inimical effects on higher plants of a toxic condition, if such in reality often exists, it is extremely doubtful whether similar effects are exerted on the bacterial flora. At least a number of compounds which are supposed to be responsible for soil toxicity have been shown to exhibit little deleterious effect on the growth of *Azotobacter*.[4] Evidence from further tests goes to show that the soil extract itself probably does not carry substances which would retard fixation.

Three soils which possessed conspicuously low fixation powers were selected and extracts made therefrom. The extracts were made into Ashby's medium and fixation tests with pure cultures of *Azotobacter* were carried out. Along with the flasks containing the extracts were controls using Ashby's solution made with distilled water. The same strain of pure culture was used for inoculating all the flasks. After 21 days the contents of the flasks were analyzed for total nitrogen. The nitrogen fixed by the culture grown on the extracts from the 3 soils was 6.5, 7.6, and 6.7 mg. nitrogen respectively. Those grown on the control flasks gave 6.8 mg. There was certainly no depressing effect registered here from using extract from soils deficient in nitrogen fixing power in substitution for distilled water in the culture medium.

The studies on nitrification (*loc. cit.*), which up to this time had included an examination of some 93 soils, were continued along with the work on fixation. Among the soils examined were a number which had exhibited signal evidence of poor nitrifying power. These in the majority of cases would be classed as poor soils from a practical agricultural standpoint, and their bacterial activity was closely correlated with this condition. Previous tests with lime had emphasized the stimulus which it exerts on nitrification, and to measure its efficiency on these soils, particularly deficient

[4] Reed, H. S., and Williams, Bruce, The effect of certain organic soil constituents upon nitrogen fixation by *Azotobacter*. Va. Agric. Exper. Sta. Tech. Bull. 4. 1915.

in their nitrifying power, would be a matter of considerable interest. Since it is likely that the humus content of a soil most intimately of all factors controls its nitrifying efficiency, it was decided to observe the effect of the addition of sugar to these soils in comparison with that produced by the addition of lime. Accordingly, two 100 gm. portions of each soil were measured out into glass jars, the moisture content brought up to 20 per cent, and the jar placed in the incubator room. To one portion of the soil 0.15 per cent $CaCo_3$ was added, and to the other 2 per cent of mannite. After 3 weeks, a period allowed for the lime and sugar to exert some influence on the bacterial flora, an optimum moisture content being maintained, 0.1 per cent ammonium sulphate was added to measure the nitrifying power of the soils. All of these soils, it will be recalled, had been tested for nitrifying power without the addition of lime, and a threefold comparison was thus afforded. Table III gives the quantities of nitrates found with and without lime.

TABLE III

COMPARATIVE NITRIFYING POWER OF CERTAIN SOILS WITH AND WITHOUT LIME

No.	MG. OF NITRATE NITROGEN PER 100 GM. SOIL		No.	MG. OF NITRATE NITROGEN PER 100 GM. SOIL	
	Without $CaCO_3$	With 0.15 per cent $CaCO_3$		Without $CaCO_3$	With 0.15 per cent $CaCO_3$
1	.....	.....	13	.....	2.12
2	.....	1.5	14	0.6	7.6
3	.....	.....	15	1.8	7.2
4	.....	.....	16	.....	1.4
5	3.3	8.8	17	1.4	8.8
6	5.1	1.2	18	.....	1
7	3.0	.....	19	1	1
8	7.2	12	20	3	5
9	.....	.....	21	1	1
10	6.5	1.6	22	.....	Trace
11	.....	2.2	23	1	1
12	.....	1			

Without the use of lime a number of soils completely failed to nitrify ammonium sulphate, and few exhibited what might be termed an average nitrifying power as judged by the method employed. While under the influence of lime there is an increase in the majority of the soils, although the stimulation is not especially

noteworthy. It appears that where there is some development of the nitrifying flora in the soil originally the effects of lime are decidedly more evident than in those soils apparently devoid of nitrifying power. The results of these tests are not to be construed as evidence depreciating the effect of lime on nitrification. They are contributory to the fact that the nitrifying flora of a soil cannot be developed merely by the use of lime in the absence of other factors more fundamental in their influence than is lime itself.

There was no formation of nitrates whatever under the influence of 2 per cent mannite. It not only failed to afford a source of energy for the nitrifying ferments, but exerted a depressing effect on the activities of such as were present. Smaller quantities of various sugars (0.5 per cent) have in some instances exerted a beneficial effect on nitrification.[5] The quantity used in these tests was possibly large enough to have a toxic effect on the soil organisms. It seems well established, however, that a satisfactory pabulum for nitrifying organisms cannot thus be so readily established.

VIRGINIA AGRICULTURAL EXPERIMENT STATION
BLACKSBURG, VA.

[5] COLEMAN, L. C., Untersuchungen über nitrifikation. Centralbl. Bakt. 20^2:401. 1908.

BRIEFER ARTICLES

THE STAINING OF WOOD FIBERS FOR PERMANENT MICROSCOPIC MOUNTS

In the preparation of wood fibers for permanent microscope mounts there is some difficulty in fixing a deep enough color, especially in the vessels of the hardwoods, when simple solutions of aniline dyes, such as safranin, are used; and the method of using such a reagent as Haidenhain's haematoxylin involves much time and loss of some elements due to washing. To avoid these difficulties a saturated solution of nigrosin in picric acid may be employed.

To macerate the fibers the original green or dry wood is soaked in a mixture of 5 per cent nitric and 5 per cent chromic acids in equal parts, with heating to about 70° C. if there is little time. A somewhat stronger solution may be used cold, and in practice has resulted in sufficient maceration in the course of one or more days, depending largely upon the kind of wood being treated. It is not necessary to macerate the complete piece of wood, as radial slices may be removed and the fibers carefully separated out with needles long before complete maceration is accomplished. After washing once in distilled water, the fibers are immediately put into the stain. To prepare the stain, saturate distilled water with picric acid and then saturate the solution of picric acid with nigrosin, and in applying to the fibers use a 25 per cent solution of the stain in distilled water. Fibers prepared according to this method are sufficiently stained, almost immediately, to a very fine light blue, which becomes darker until a deep blue-black is reached as they remain longer in the stain. In case the fibers do not take up the color, which seldom happens in the case of wood fibers, but is often the case in certain textile fibers, a stronger solution may be used. Even with the full strength, certain textile fibers, apparently those like cotton which contains no lignin, will not stain after a prolonged treatment. After staining, the material may be dehydrated and mounted in balsam in the usual manner. Benzol balsam is the kind we have employed, although there appears to be no reason why xylol balsam should not be used. The color will not hold in glycerin jelly mounts. In case a precipitate appears it may be

removed by adding a drop of concentrated hydrochloric acid to the distilled water in which the fibers are washed just after staining.

To secure permanent mounts showing a differentiation between groundwood and sulphite pulp as ordinarily found in newsprint, the following modification is of value. Leave the newsprint, which has been reduced to pulp, in a moderately strong solution of fuchsin for some hours, dehydrate with absolute alcohol and transfer to benzol, transfer back to a moderate solution of nigrosin in absolute alcohol, and after a few minutes transfer again to benzol. Superfluous stain may be washed out with either fresh absolute alcohol or with benzol. Mount in balsam. The groundwood shows red while the sulphite is blue. Bordered pits in some of the tracheids of the sulphite show a red torus and the pit openings are often reddish.

Further studies are being carried on to determine the qualities of this method for staining other types of material.—H. N. Lee, *Forest Products Laboratories of Canada, Montreal, Canada.*

CURRENT LITERATURE

BOOK REVIEWS

Individuality in organisms

Continuing his important and illuminating contributions to philosophical biology, CHILD[1] presents in clear and masterly fashion a new conception of the nature of the individuality of organisms which he has developed through many years of investigation of development and reproduction in the lower animals. The book deals with the very fundamental problem of the nature of the unity and order in the organism, the constancy and course of development, the maintenance of individuality in a changing environment, and the processes by which physiological isolation and reproduction occur. As the new theory of individuality applies to plants as well as to animals, and as much supporting evidence has been obtained from the study of plants, the discussion will prove to be extremely valuable to botanists as well as zoologists, and to all who are interested in the philosophical aspects of biological discussion.

The first chapter discusses the problem of the nature of individuality, which resolves itself into the problem of the nature, origin, and maintenance of the definite space and time relations existing among the reactions occurring in the fundamental reaction system, the protoplasm. A new dynamic theory of the origin and nature of organic individuality is presented in the second chapter. The way is prepared for it by a critical consideration of various theories which have been advanced in the past, such as the corpuscular theories of WEISMANN and others, which necessitate the assumption of an ordering principle or entelechy, the dualistic theories, physico-chemical hypotheses, chemical correlation hypotheses, theories of polarity and symmetry, etc.

The organic individual is conceived to be a system of relations between the protoplasmic substratum and the chemical reactions of metabolism; and the foundation of organic unity, according to CHILD, is the transmission of dynamic change of some kind through the protoplasm. The essential features of this dynamic conception of individuality are simple, and are presented with convincing force and clearness. An undifferentiated mass of protoplasm which has a uniform rate of metabolism in all its parts, and which is capable of becoming an individual, forms the starting-point. This mass is acted upon at some point by external factors which act as stimuli, with the result that metabolism is increased at the point of stimulation. In this purely mechanistic

[1] CHILD, C. M., Individuality in organisms. 12mo. pp. x+213. The University of Chicago Press. 1915. $1.25.

way we have established a region of relatively high metabolic rate in the undifferentiated protoplasmic mass. From this point of high metabolic rate there is a radiation of dynamic change over the surface or through the mass of protoplasm. It is a transmissive, not a transportive, change, and in some way involves an increase in metabolic activity as it spreads over or through the protoplasm. In other words, there is a wave of increased chemical activity spreading away from the point of impinging stimulus.

This metabolic change cannot be transmitted to indefinite distances, for the intensity of the metabolic change decreases with transmission. This transmission-decrement partly determines the limits of transmission. Other factors upon which the limit of transmission depends are the intensity of the original stimulus and the relative conductivity of the protoplasm. The limit of transmission determines the size limit of the individual, for parts that lie beyond the transmission limit remain physiologically isolated.

Momentary action of the stimulus may lead only to a temporary increase in metabolic rate at the point of origin, but prolonged or frequent excitation may lead to more or less permanent changes in the protoplasm, chief among which is an increased irritability. The greatest increase in irritability occurs in the region of highest metabolic rate, which is the region of stimulus, and is progressively less in regions of lower and lower metabolic rates, reaching zero at the limit of transmission. Thus we may have established a gradient in the condition of the protoplasm, an irritability gradient, which constitutes the substratum for a persistent metabolic gradient independent of the local stimulus. For as soon as a persistent irritability gradient is established, uniform stimulation will be followed by a graded metabolism dependent upon the degree of irritability of each axial level. Such persistent metabolic gradients are looked upon as the starting-point of organization. They are factors in determining the direction of growth and differentiation, and are therefore the basis of the space and time relations of development.

The phenomenon of dominance of one part or region over other regions of the organism during development is simply a result of these differences in metabolic rates, levels of high rate dominating and controlling those of lower rate, and the interrelations of the parts of the organism, depending thus upon differences of metabolic rate, constitute the foundation of the unity and order exhibited by it. From this standpoint the organic individual is viewed as consisting of one or more gradients in a protoplasmic mass of specific physico-chemical constitution; and the process of becoming an individual is merely the process of establishing the necessary gradients. Such gradients, which arise *de novo* in response to external conditions, and cannot *originate* in any other way, may nevertheless become hereditary and persist through many generations when once established.

This dynamic theory is distinguished by its satisfactory interpretation of organic unity in terms of differences in rate of metabolism and of transmitted change, rather than in terms of hypothetical organization and transportation

of chemicals. And, being entirely mechanistic, it has the great merit of offering the possibility of experimental advancement toward a complete solution of the problems of individuality.

The three succeeding chapters present some of the evidence which supports this conception of the origin and nature of individuality. The third chapter presents the evidence for the existence of metabolic gradients. This evidence consists mainly in the demonstration of susceptibility, respiratory, and electric potential gradients in the organism coinciding with the supposed metabolic gradients. Embryological evidence for the existence of axial metabolic gradients, and the developmental gradients in cases of asexual and experimental reproductions are considered. The evidence is varied and extensive, and comes from a study of both animals and plants. It all agrees in showing that axial gradients in dynamic processes are characteristic features of organic constitution.

Chap. iv considers the evidence for the existence of physiological dominance in the process of individuation, in support of the conception that "the organic individual is fundamentally a dynamic relation of dominance and subordination, associated with and resulting from the establishment of a metabolic gradient or gradients." The evidence is obtained principally from experimental reproduction in plants and animals, and demonstrates the independence of apical regions in the developmental process, and the control of the development of other levels of the major axis by this independent apical region. The apical regions are the regions of most rapid metabolism, and they are physiologically dominant over the other subordinate levels.

Chap. v gives evidence bearing upon the problems of range of dominance, physiological isolation, and experimental reproduction. The experiments deal with the control of the spatial relations of parts and of the range of dominance by altering the length of metabolic gradients; the obliteration and redetermination of axial gradients; the extension of dominance during development; and physiological isolation and reproduction in plants. The final chapter is a general discussion of individuality from the new viewpoint, and considers such topics as the nature of dominance and inhibition, the origin of metabolic gradients and dominance, the relation of morphological differentiation to metabolic rates, the fundamental reaction system (protoplasm), the nature of agamic and gametic reproduction, and closes with a brief but trenchant discussion of such large problems as heredity and evolution from the dynamic standpoint.

An interesting contrast is drawn between animals and plants in discussing the fundamental reaction system. In animals the independent self-determining apical region begins the process of differentiation, and if the self-determined changes go far enough, they result in the formation of a nervous system, physiologically the most stable structure of the whole animal body. The greatest differentiation occurs in the region of highest metabolic rate. But in the plant the apical region remains undifferentiated, and the degree of differentiation increases with increasing distance from the apical point, a situation exactly the reverse of that found in animals. This difference between the animal and

plant is traced to a difference in physiological stability of their respective protoplasms. In animals the stable molecules which form nervous tissue accumulate in spite of the high metabolic rate, while in plants the degree of physiological stability is low, and the high metabolic rate of the apical point may mobilize the whole substratum. It is only in regions of lower rate that the accumulations of visible structure can occur. In this contrast we see one of the fundamental differences between the two classes of organisms.

The reader is favorably impressed by the thoughtful style and illuminating manner in which the philosophical discussion proceeds. The dynamic conception of individuality presented in this work seems so reasonable, and the marshalled evidence is so clear and convincing, that it is bound to exert a profound influence on biological thought and theory. The author modestly states that this conception is "manifestly far from being a complete solution of the problem of organic individuality." It is an excellent working hypothesis, however, suggests many lines of experimental approach toward a final solution, and offers an attractive substitute for the unsatisfactory vitalistic conceptions which have held until now so prominent a place in our philosophy of organic life.—CHARLES A. SHULL.

NOTES FOR STUDENTS

Linkage and crossing-over in oats.—SURFACE[2] is continuing in *Genetics* a series of studies in oat breeding of which two former papers have appeared in the Annual Report of the Maine Agricultural Experiment Station. It will be very gratifying indeed if this new journal makes so strong an appeal to geneticists that work of high grade will no longer be buried with such ephemeral literature as that which makes up the bulk of nearly every station report.

In crosses between strains of wild and cultivated oats (*Avena fatua* and *A. sativa*), SURFACE has studied particularly the inheritance of qualitative characters in the flowering glumes. The base of the fertile floret in the wild oat is characterized by a broad callus associated with ease of abscission from the spikelet, whereas the lack of the callus in the cultivated oat is associated with persistence of the floret. First generation hybrids present the callus in an intermediate condition, and in subsequent generations typical Mendelian segregation takes place. There are, therefore, three types of bases, called, for short, "cultivated," "intermediate," and "wild." Perfectly correlated with the "cultivated" base are the almost complete absence of awns on the lower flowering glume, their complete absence from the upper flowering glume, the absence of pubescence from the rhachilla, the slight pubescence at the base of the first floret, and its complete absence at the base of the second floret. Conversely, the "wild" base is perfectly correlated with the presence of well de-

[2] SURFACE, FRANK M., Studies on oat breeding. III. On the inheritance of certain glume characters in the cross *Avena fatua*×*A. sativa* var. *Kherson*. Genetics 1:252–286. 1916.

veloped awns on both flowering glumes, a densely pubescent rhachilla, and dense pubescence at the base of both fertile florets. The "intermediate" base, as would be expected, is associated with an intermediate development of the other characters. Thus, in some spikelets the first floret has a medium sized awn, but the second has none; likewise, the first floret has pubescence at the base, but the second is glabrous. It is on the basis of differences between the first and second florets that SURFACE is able to correlate 7 putatively distinct characters with the "cultivated" type of base, but those whose view of Mendelian inheritance is less formal than the author's will wish very clear evidence before admitting them as distinct. SURFACE himself has suggested, following NILSSON-EHLE, that characters may be genetically present in an individual, but not manifest because of environmental conditions. In some strains of oats, for example, awns are potentially present, but develop only under certain external conditions. What is true of a population, acted upon by varying environmental factors, may equally well be true of homologous parts of a single individual, conditioned in development by their position on that individual.

Turning to a concrete case, the spikelet of *Avena* is composed of 2, or at most 3, fertile florets, presenting a gradation from the first, which is large and in every way the most highly developed, to the third, which is ordinarily a sterile or even vestigial structure. In a reduction series composed of so few members, and with so steep a gradient, we have ideal conditions for a variable character to be manifest in the first member and latent in the second. At any rate the reviewer would look for a physiological rather than a genetical explanation for the situation as regards awns and pubescence in the spikelet of *Avena*. If the first flowering glume is awned, it is a fair assumption that the second is potentially the same, even though its position be such that manifestation of the character is a physiological impossibility. Perhaps an underlying basis for the whole group of correlations might be found in the diminution of the vascular supply between the base and apex of the spikelet.

In addition to the characters showing perfect correlation, SURFACE discovered two pairs of characters showing partial linkage. The factor for pubescence on the back of the first flowering glume showed linkage with the factor for black color of the glume, and the pubescence of the back of the second flowering glume showed linkage with the "wild" base. In respect to these characters the data are too involved to be repeated here, but as interpreted by SURFACE they show (1) that the presence of pubescence is a dominant character in the case of the first flowering glume, but a recessive character in the case of the second glume, and (2) that the factor for pubescence of the lower glume is a basic pubescence factor, in the abscence of which the factor for pubescence of the second glume is without effect. The bare facts upon which SURFACE bases these conclusions are as follows. The first hybrid generation has the lower flowering glume pubescent, the upper smooth. In the one parent, *Avena fatua*, both glumes are pubescent; in the other, *A. sativa*,

both are smooth. In no case does segregation in the second or third hybrid generation result in spikelets with the first glume smooth and the second pubescent.

It is not easy to accept a hypothesis which limits the operation of a Mendelian factor to one of two identical and adjacent morphological structures, nor to believe that the character of pubescence is in the case of one of these structures due to a dominant and in the other case to a recessive factor. Furthermore, unless the reviewer has failed to comprehend the data, a much simpler hypothesis will account for the situation. Let us postulate a single dominant factor for the glume pubescence; this factor is linked with the factor for black glumes. A second factor, linked with the factor for "cultivated" base, may be conceived of as a partial inhibitor of the pubescence factor. In accordance with the idea of position effect, it would operate most powerfully upon the second glume, resulting in a first generation hybrid with the pubescence only partially suppressed on the first glume, but completely suppressed on the second. According to this conception, and taking no account of crossing-over, all black-glumed plants in the second hybrid generation would have at least the lower glume pubescent. Both blacks and non-blacks would have undergone segregation with regard to the inhibiting factor, but since blacks alone carry the pubescence factor, a complete loss of the inhibitor could be manifested only by blacks, one-fourth of which would appear, in accordance with expectation, fully pubescent on both glumes. It appears to the reviewer that these considerations apply to the numerical data as well as one could expect.

The cross-overs detected by SURFACE were exceptions to the linkages between the factors for pubescent glumes and black (about 0.7 per cent), and the inhibitor of glume pubescence and the factor for "cultivated" base (about 1.5 per cent).

It seems unfortunate that the author has not used the conventional terminology of the grass inflorescence in his otherwise exceedingly well presented paper. Although he defines his terms, the paper is a long one, and if merely glanced over, the unusual terminology might be perplexing if not misleading. "Head" is used for panicle; "grain" for the caryopsis with its adhering lemma and palea; "pedicel of lower grain" for the portion of the rhachilla between the two fertile florets; "pedicel of upper grain" for the portion of the rhachilla above the second floret; "flowering glumes" for the flowering glume and lemma of the same floret; "dorsal side of grain" for the lemma; "ventral side of grain" for the palea.—H. H. BARTLETT.

Cohesion of water and the rise of sap.—From theoretical considerations RENNER[3] draws the following important conclusions: (1) The vapor pressure

[3] RENNER, O., Theoretische und Experimentalles zur Kohäsionstheorie der Wasserbewegung. Jahrb. Wiss. Bot. **56**:617–667. 1915. PFEFFER'S Zeitschrift.

in fully turgid cells is equal to that of pure water, and of plasmolyzed cells to that of their cell sap. The vapor pressure of plasmolyzed cells with 100 atmospheres osmotic pressure is 7 per cent less than that of pure water. (2) Water movement in parenchyma is dependent upon difference in degree of turgescence and independent of difference in osmotic pressure. (3) If in a wilted leaf the osmotic pressure of the parenchyma is *P* atmospheres, there exists in the adjacent vessels a tension of *P*-1 atmospheres, and the vapor pressure of the water in the vessels is correspondingly reduced. (4) The energy potentials for moving water in the plant are the potential differences in imbibitional energy, osmotic energy, and hydrostatic pressure. These potentials originate from the transformation of a part of the energy potential which exists between the surface cells and the atmosphere in the way of vapor pressure differences. The rest of the primary potential is usable by transpiration alone.

In the experimental part RENNER makes use of the annulus of fern sporangia (*Polystichum Filix-mas*) for measuring the tensile strength of water under the conditions in which it exists in plant cells. The walls of these cells are impermeable to cane sugar in aqueous solution, and to certain substances in very low concentration within the cells, but they are more or less permeable to salts. In a solution of cane sugar with an osmotic pressure of 200 atmospheres the annulus cells are deformed and the sporangia opened, but no gas bubbles are formed within the cells (there is not a throwing movement of the sporangia), although the water within is stretched equivalent to about 200 atmospheres. Since the osmotic pressure of sugar solutions was not sufficient, and the walls were permeable to salts, RENNER turned to the vapor pressure method of determining the tensile strength of the water within these cells. Over a saturated solution of sodium chloride almost all of the sporangia spring with the formation of gas bubbles in the annulus cells. In the few not springing, the water in the annulus cells must be stretched approximately equivalent to the osmotic pressure of the solution, 368 atmospheres. There was little springing of the sporangia until the solutions used exceeded 300 atmospheres osmotic pressure.

Working independently, but with similar methods, URSPRUNG[4] concludes that the water in annulus cells of fern (*Pteris*, *Scolopendrium*) sporangia are under a tension (a stretch) of somewhat more than 300 atmospheres at the time most of the sporangia spring. These determinations of cohesion exceed the values obtained by DIXON[5] in his measurements in glass tubes.

HALLE,[6] a student of RENNER, finds that generally when plant cells lose water by evaporation the protoplasm is not immediately withdrawn from the

[4] URSPRUNG, A., Über die Kohäsion des Wassers im Farnannulus. Ber. Deutsch. Bot. Gesells. **33**:153–162. 1915.

[5] BOT. GAZ. **60**:74, 75. 1915.

[6] HALLE, HANS, Untersuchungen über Welken, Vertrocken, und Wiederstraffwerden, Flora **108**:73–126. 1915. Written by RENNER after the death of HALLE at the front.

wall, but the wall is deformed with the protoplast, owing to the cohesion of the contained water. Very considerable negative pressures or tensions of water can thus be developed in plant cells before bubble formation occurs; 250 atmospheres in the stellate hairs of *Verbascum thapsiforme*, less than 20 atmospheres in the hairs of *Lychnis coronaria*, and still less in the ringed velamen cells of orchids and the pith of orchid and *Sambucus* stems. This is independent of living protoplasm, for it occurs in dead cells. In thin-walled parenchyma the cells may be completely crushed without gas appearing, while in thick-walled parenchyma there is a considerable deformation of the walls before gas accumulates within the cells. In fully wilted leaves of *Alliaria officinalis* the tracheae are still free from gas, which means that the water within them must be under negative pressure equal to the osmotic pressure of the parenchyma. Vessels in storage organs withstand little negative pressure, while those of actively conducting tissue develop great negative pressure without bubble formation within them. If in wilted tissue air is admitted to a vessel by a wound, it does not pass through the side walls to intact vessels, although they bear water under considerable tension. When both sides of the cell wall are water free, air accumulates within rapidly even under slight negative pressure; while the cell is full of water, air does not accumulate negative pressure within even under many atmospheres.

In another article URSPRUNG[7] raises the question of the cause of bubble formation in "Tonometern," any apparatus used for the qualitative or quantitative determination of fluid cohesion. For water he believes bubble formation is not determined by the limits of cohesion, for the cohesion of water as measured by such instruments falls far below the cohesion calculated by VAN DER WAALS on the theoretical basis. The great variation in the tension at which bubbles appear, even under like conditions, also argues against the limits of cohesion being the cause of bubble formation. Since all evidence indicates that adhesion of water to the wall exceeds its cohesion, URSPRUNG believes that the limits of adhesion do not determine bubble formation. GERNEZ found that in supersaturated solutions of gases bubbles collect on the surface of containing or inserted solids and not within the liquid itself, because these surfaces bear adsorbed gas as inoculation centers. URSPRUNG believes that adsorbed gases (in very thin layers of submicronic or amicronic thickness) on the walls of the "Tonometern" cause bubble formation. Hence all attempted measurements of cohesion of water by such instruments give values far short of the actual cohesion. They measure rather the tension at which gas bubbles form under the influence of inoculating centers of adsorbed gases and the (gas) supersaturated condition of the water in such instruments. As bearing upon cohesion within tracheae, URSPRUNG emphasizes the fact that wood tissue adsorbs gas readily. The author uses considerable space in criticizing DIXON's experiments upon cohesion of water.

[7] URSPRUNG, A., Über die Blasenbildung in Tonometern. Ber. Deutsch. Bot. Gesells. **33**:140–153. 1915.

The four articles reviewed indicate that cohesive stretching of water is of great significance in plants. They show the magnitude of force thus available for work and give much insight into the conditions under which it is operative; also they add evidence for the cohesion theory of the rise of sap.

COPELAND[8] has devised a very simple but ingenious piece of apparatus for determining various facts concerning the movement of water through stems of lianas. From his measurements he concludes that the resistance offered by stems to water flow through them is very much less than claimed by other workers in this field; that the tension in the water column of the stem assumed by the cohesion theory does not exist; and that the living cells along the stem play no essential part in the movement of the water through it. COPELAND believes that the main problem of rise of sap remains, as he earlier stated,[9] "Why is this atmospheric pressure exhausted so slowly with the ascent of the tree that whatever height is reached, and however rapidly and forcibly water may be drawn from the wood, some pressure always remains?" Notwithstanding the ingenious character of these experiments and the suggestiveness of the results, much more work of an analytical sort is needed to establish a new theory of the rise of sap or to dispose entirely of the cohesion theory.—WILLIAM CROCKER.

Structure of the Boleti.—Very few studies on the finer structural details of the Boleti have been published. These have been fragmentary observations occasionally employed to supplement specific diagnoses drawn from the grosser features, or to interpret certain surface characters. A comparative study of the structure of all parts of the plant in a large number of species is greatly needed, and especially a study of the origin and differentiation of its parts is much to be desired. A contribution to the former phase of the subject is now presented by YATES[10] in the study of 6 Californian species, supplemented by two eastern ones.

In general, there is not such a marked differentiation of the tissues, when the size of the plants is considered, as one might expect who has not given some attention to these plants. According to the author's interpretation, the tissues of the pileus and stipe are differentiated into two main zones: an outer, the cortex ("rind"); and an inner, the trama ("context"). In some species the cortex of the pileus consists of elongate vertical hyphae, which in dry species give the pileus a tomentose appearance, as in *Boletus chrysenteron*. In the viscid species the outer layer of the walls of these hyphae is more or less gelatinized and the pileus is not tomentose, as in *B. granulatus*, *B. luteus*, and *B. cali-*

[8] COPELAND, E. B., Über das Saftsteigen. Jahrb. Wiss. Bot. **56**:447–459. 1915. PFEFFER'S Zeitschrift.

[9] COPELAND, E. B., BOT. GAZ. **34**:161–193, 260–283. 1902.

[10] YATES, H. S., The comparative histology of certain Californian Boletaceae. Univ. Calif. Publ. Bot. **6**:221–274. *pls. 21–25*. 1916.

fornicus (Murrill),[11] the last being subtomentose. In others the gelatinous matrix is firm and the pileus not viscid, or slightly so when wet, as in *B. edulis* and its variety *separans*.

Forms with a somewhat similar structure of the pileus present three zones: (1) in *B. Eastwoodiae* (Murrill),[12] form *A*, there is an outer zone of vertical interwoven brownish hairs which sometimes gelatinize to such an extent as to disappear, an intermediate zone of compactly woven hyphae, and the looser trama; (2) in *B. Eastwoodiae*, form *B*, the outer zone consists of rather distant hairs arising from a compact brown rind of interwoven hyphae; while (3) in *B. chrysenteron*, form *E*, there is a zone of densely interwoven, small brown hyphae between the palisade of hairs and the loose trama. In other species the structure of the pileus is more homogeneous, consisting of interwoven hyphae, larger and with a more open mesh in the trama, smaller and more compact and dark colored in the "rind." Such species have a glabrous pileus, as in *B. auriflammeus* and *B. Frostii*, there being 3 zones of different density.

The hymenophore (=stratum of tubes) is very uniform in the species studied. Cystidia are said to be wanting in most of those examined. In *B. granulatus* and *B. californicus* the cystidia form tufts of clavate cells which arise in the trama and project beyond the surface of the hymenium. They also occur on the dissepiment edges and on the stem.[13] In *B. luteus* the tufts of cystidia are smaller.

The general structure of the stipe is quite uniform. The hyphae in general are parallel with its axis, in some species almost strictly parallel, in others more or less interwoven. The central portion is loose and the hyphae of larger diameter; the outer portion compact and the hyphae of smaller diameter.[14] The surface of the stipe, then, is often characterized by outgrowths of short hyphae, cylindrical, clavate, or capitate cells, either in tufts, or covering the entire portion of the stem, thus forming a palisade layer. In the latter case the author speaks of this palisade as the "rind" (in *B. auriflammeus*). The "context" here then includes all the hyphae which extend more or less parallel with the axis of the stipe, that is, both "rind" and "context" of species lacking the palisade layer.

This palisade layer on the stipe in *B. auriflammeus* forms the tomentum, and in the opinion of the reviewer represents merely the vesture of the stem, not the cortex ("rind"). Cortex and medulla ("context") are of the same character as in those species with a smooth stipe, then, or where the vesture of the stipe is composed of isolated tufts of cells. This interpretation of the tomentum on the stipe of *B. auriflammeus* finds confirmation in the fact that the vesture of the stem is usually "reticulate" and represents very likely

[11] *Rostkovites californicus* Murrill, Mycologia **7**:44. 1915.

[12] *Suillellus Eastwoodiae* Murrill, N. Am. Flora **9**:152. 1910.

[13] Absent or very rare in *B. brevipes* Pk., which MURRILL unites with *B. granulatus*.

[14] A general feature in the stipe of most agarics.

a depauperate condition of the hymenophore extending down on the stem, as in *B. edulis* described by YATES (form *B. pl. 22. fig. 10*) and by PATOUILLARD (Tab. Analyt. Fung. no. 9, 1883). Besides a few basidia, bearing spores, in this reticle on the stem, PATOUILLARD states that cystidia are also present similar to those in the normal hymenium of this species, while YATES says that cystidia are not present in the forms he examined, although one would suspect their presence from his figure. This vesture on the stem of some species may grade from a reticle above to an even tomentum below, or to tufts more or less crowded, or without a reticle tufts more or less crowded or disparate over the stem (*B. luridus*, for example). Similar examples of depauperate hymenia are abundant in the Basidiomycetes, and even occur in the Ascomycetes, in *Glocoglossum difforme*, for example (see DURAND, Ann. Myc. **6**:421. *figs. 160–162.* 1908).

Some of the different forms of *B. chrysenteron*[15] described may be interpreted as due to variations in the vesture of the stipe, the tomentum of the pileus, and the color changes resulting from the presence of oxydases, due to age, vigor of growth, relation of the dissepiment edges to the stipe surface during the origin of the hymenophore, etc., which cannot be enlarged upon here. However, the author makes no mention of the structural features of the usually sterile dissepiment edges, which in many species of agarics, at least, bear a very interesting relation to the vesture of the stipe.

The author very properly remarks that, by authority of the Third Botanical Congress (Brussels, 1910), FRIES'S *Systema Mycologicum*, 1821, is the starting-point for the nomenclature of the Hymenomycetes. But he follows MURRILL'S nomenclature[16] of the Boleti, perhaps unaware that this author does not recognize the rules adopted by the Vienna and Brussels congresses, the two largest and most representative legislative assemblies of botanists ever held. One of the deplorable results of this hunting for names by groping in the mystic and heroic age of mycology is well exemplified by the attempt to introduce the generic name *Ceriomyces* for the section containing the largest number and most typical species of the genus *Boletus*, and citing as the type of this genus *Ceriomyces crassus* Battarra.[17] It is not likely that well informed botanists will discard the name *Boletus edulis*, which is in strict conformity with the international rules,[18] and use in its stead *Ceriomyces crassus*, a con-

[15] The form *C* is very likely *B. subtomentosus*. Some students unite *B. chrysenteron* and *B. subtomentosus*. For some of the varieties of these two species, see BATAILLE, F., Les bolets, classification et determination des espèces. pp. 1–30. Besançon. 1908.

[16] N. Am. Flora **9**:133–161. 1910.

[17] BATTARRA, J. A., Fungi Agric. Arim. Hist. *62, 63. pl. 29.* 1755.

[18] The generic name *Boletus* was properly retained by HENNINGS (ENGLER und PRANTL, Die Nat. Pflanzenfam. 1^{**}:191. 1898) for the section containing the larger number of species, including *B. edulis*, his action being entirely in accordance with the principle of the international rules adopted at Vienna in 1905, and at Brussels in 1910 (see Article 45).

fusing medley of species, for European mycologists long since an undecipherable rebus.—GEO. F. ATKINSON.

Patrogenesis.—COLLINS and KEMPTON,[19] working on intergeneric hybridism in the tribe Maydeae, have had the great good fortune to bring to light a new case of the phenomenon discovered in *Fragaria* by MILLARDET, and termed by him "hybridation sans croisement ou fausse hybridation." The hybrid *Tripsacum dactyloides*×*Euchlaena mexicana*, carried through 3 generations, has shown no trace of characters derived from *Tripsacum*, aside from the fact that the original hybrid seed was "an unmistakable *Tripsacum* seed." Characters of *Euchlaena* appeared with the first leaves, and in further stages of development the plant was an almost normal *Euchlaena*.

In attempting to explain the complete exclusion of maternal characters from the hybrid, the authors have discussed two hypotheses: (1) that the *Euchlaena* characters have completely masked those of the *Tripsacum*, and (2) that the embryo of the original hybrid developed only from the male nucleus, which must be regarded as having dispossessed the female nucleus with which it would have been expected to unite. COLLINS and KEMPTON adopt the latter hypothesis, and look upon their hybrid as exemplifying a new type of inheritance, which they call "patrogenesis" in order to place the phenomenon in what they regard as a proper contrast with parthenogenesis. We may well doubt, in the absence of cytological data, whether this explanation is probable enough to warrant the introduction of a new term. BATESON's terms monolepsis and amphilepsis, indicating hybrids in which the characters are brought in respectively from only one or from both parents, have already been introduced, and have the advantage that they imply nothing as to cytological conditions.

Maternal monolepsis is well known in the Orchidaceae, especially in the intergeneric hybrids between *Zygopetalum Mackayi* and species of *Odontoglossum*, *Lycaste*, and *Oncidium*. Paternal monolepsis is a rarer phenomenon, and its discovery in intergeneric grass hybrids is most interesting. That it is to be explained by merogony, however, should not be too incautiously assumed. It will be recalled that a similar explanation of DEVRIES' patroclinic hybrids in *Oenothera* was brought forward, with even some show of cytological evidence, but was afterward disproved.

In the first hybrid generation COLLINS and KEMPTON had only one plant of their *Tripsacum*×*Euchlaena*. There is no evidence, therefore, that this generation may not consist normally of more than one type, as in the case of many *Oenothera* hybrids. Certain evidence obtained by COLLINS and KEMPTON themselves almost tempts one to predict that twin hybrids will be found if it is possible to get large enough progenies.

[19] COLLINS, G. N., and KEMPTON, J. H., Patrogenesis. Jour. Heredity 7:106–118. 1916.

Euchlaena and maize are rather closely related to one another, and cross spontaneously. Seed of the former imported from Mexico is often obviously hybridized. That from Durango, whence COLLINS and KEMPTON got their strain, is so impure that the parent of their hybrid is not free from suspicion of contamination. A priori, therefore, we should expect similarity of behavior in the hybrids between these two closely related plants and the distantly related *Tripsacum*. Nevertheless, all the plants of *Tripsacum*×*Mais* thus far raised have shown maternal characters only, in marked contrast to the paternal characters of the corresponding hybrid *Tripsacum*×*Euchlaena*. More first generation plants are greatly to be desired, but there is difficulty in getting them because the parent species can seldom be brought into flower simultaneously.

The authors lead us to expect cytological data bearing on the question raised by their very important discovery.—H. H. BARTLETT.

Negative osmosis.—In osmotic experiments it has been found that the flow of water is not always from the less concentrated toward the more concentrated solution. Several cases have been reported in which an opposite flow of water occurred, or in which a movement of water was observed in dealing with solutions with the same osmotic pressure. This is called negative or abnormal osmosis. FREUNDLICH[20] has given us a discussion of these experiments, has defined the conditions under which abnormal osmosis can take place, and has dealt with the cause of it. It appears that such movements of water are caused by the development of an electric current through the membrane, and the water moves in an electroendosmotic manner in the current. The generation of this current and the consequent electroendosmosis can take place in two sets of conditions: (1) when the membrane is permeable to both solvent and solute the ions of the electrolyte are adsorbed by the membrane, their transport numbers changed, and a difference of electric potential on opposite sides of the membrane established, which leads to the starting of an electric current; (2) when the membrane allows only one of the ions of the electrolyte to pass through, the other ion being held back. This semipermeability toward one ion leads to a difference of potential, an electric current is established, and water moves across the membrane by electroendosmosis. This can take place only when the electrolytes on opposite sides of the membrane are different and are such that the ions may react with each other and set free electrical changes.—F. E. DENNY.

Growth in Laminariaceae.—Miss FALLIS[21] reports experimental data on the growth of several species of Laminariaceae. She worked on species of *Laminaria*, *Agarum*, *Cymathaere*, *Egregia*, *Alaria*, and *Nereocystis*. She found

[20] FREUNDLICH, H., Über abnorme Osmosen. Kolloid. Zeitschr. **18**:11–16. 1916.

[21] FALLIS, ANNIE L., Growth in some Laminariaceae. Puget Sound Marine Sta. Publ. **1**:137–155. *pls. 25–28*. 1916.

by experiment that the plants grow as well suspended from a raft by means of cloth strings as they do when attached naturally to the rocks by their own holdfasts. She found also that the removal of the holdfast and even of a considerable portion of the stipe does not affect the growth of the remainder of the plant. The removal of the tip of the blade produces only a negligible effect so long as the basal portion is left intact. Pieces of the blades even as small as 1 mm. square were found to grow when placed in a cloth bag attached to a raft. In kelps having a very short stipe it was found that the region of greatest growth in the post-juvenile stages is near the base of the blade, the main growth of the stipe occurring during the younger stages. She found that the kelps experimented upon grow almost twice as rapidly during the daytime as during the night.

The results reported coordinate well with the small degree of physiological specialization of parts that is found in such genera as *Laminaria* and other leaflike kelps. The data are interpreted largely from the viewpoint of their bearing on the location of the region of greatest growth. Only slight attention is given to the interpretation of the data in their relation to regeneration, and none at all to their relation to coordination.—GEORGE B. RIGG.

Taxonomic notes.—BRANDEGEE[22] has described new species in *Aristolochia* (2), *Jatropha*, *Lycium*, *Galvezia*, *Maximowiczia*, and *Orobanche* from Lower California; in *Aristolochia* and *Asclepias* from Mexico; and in *Sedum* and *Antirrhinum* from California.

MAXON,[23] in continuation of his studies of tropical American ferns, has presented three groups of *Polypodium*, "whose species have for the most part been greatly misunderstood." One of these groups is *P. trichomanoides* and its American allies, including a critical discussion of 26 species. Another group is *P. furfuraceum* and related species, including 21 species, 5 of which are new. The third group is *P. squammatum* and its allies, including 17 species, 5 of which are new. In addition to the new species in these groups, 5 additional new species of *Polypodium* are described, and 2 new species of *Notholaena*.

MILLSPAUGH,[24] in continuation of his studies of North American Euphorbiaceae, has recognized the following segregates from *Euphorbia: Chamaesyce* S. F. Gray, with 9 new species and 84 old ones; *Eumecanthus* Kl. and Gke., to which 41 species are transferred; *Aklema* Raf., to which 19 species are transferred. New species are also described in *Acalypha* (2), *Croton* (3), and *Tragia*.—J. M. C.

[22] BRANDEGEE, T. S., Species novae vel minus cognitae. Univ. Calif. Publ. Bot. **6**:357–361. 1916.

[23] MAXON, WILLIAM R., Studies of tropical American ferns. no. 6. Contrib. U.S. Nat. Herb. **17**:541–608. *pls. 32–43.* 1916.

[24] MILLSPAUGH, C. F., Contributions to North American Euphorbiaceae VI. Publ. Field Mus. Nat. Hist. Bot. Series **2**:401–420. 1916.

Floral evolution.—In a series of papers published in *New Phytologist* during 1911 and 1912, WERNHAM has discussed floral evolution, especially with reference to the phylogeny of the Sympetalae. The last paper[25] presents the summary and conclusions, and it is announced that the series has now appeared in book form. The immense amount of material presented cannot be mentioned in a review, but the general conclusion is that the Sympetalae are polyphyletic, having been derived from the Archichlamydeae along 7 distinct lines. The names given by the author to these lines will indicate the relationship of the various sympetalous orders to those of the Archichlamydeae. The lines are as follows: (1) Centrospermae-Primulales; (2) Geraniales-Ericales; (3) Guttiferales-Ebenales; (4) Geraniales (Plantaginales)-Contortae-Tubiflorae; (5) Calyciflorae-Umbelliflorae-Rubiales-Dipsacales; (6) Calyciflorae-Campanulatae; (7) Calyciflorae-Passiflorales-Cucurbitales. There is also a very useful discussion of the method of determining plant affinities and of the principles of classification.—J. M. C.

Resistance against attack of dodder.—By growing *Cuscuta Gronovii* on a great variety of hosts, GERTZ[26] has studied various means of protection possessed by plants against the attack of dodder. The main means found are mechanical resistance to penetration, high concentration of oxalic acid, and presence of latex, certain alkaloids, or ethereal oils. Various alkaloids and ethereal oils, in the concentration existing in the hosts tested, vary greatly in their effectiveness from indifferent to rather highly toxic. In comparing his results with rather fully reported results of other workers, GERTZ concludes that different species of dodder vary greatly in their resistance to a given protective substance. He notes the presence of the 3 characters of dodder often reported: resorption of the basal part of the sprout, ability to act in part as an autotroph by chlorophyll development, and impermeability of haustoria to certain toxic materials. This subject is in need of thorough microchemical and physiological study.—WILLIAM CROCKER.

Cercospora beticola.—POOL and MCKAY[27, 28] have made a detailed study of the parasitism of *Cercospora beticola* on the sugar beet (*Beta vulgaris*), paying special attention to climatic factors and the mode of infection. The leaves that show maximum stomatal opening, both in aperture and in duration of opening, showed the greatest susceptibility to infection. Factors that favor

[25] WERNHAM, H. F., Floral evolution, with particular reference to the sympetalous dicotyledons. New Phytol. **11**:373–397. 1912.

[26] GERTZ, OTTO., Über die Schutzmittel einiger Pflanzen gegen schmarotzende *Cuscuta*. Jahrb. Wiss. Bot. **56**:123–154. 1915. PFEFFER'S Festschrift.

[27] POOL, V. W., and MCKAY, M. B., Relation of stomatal movement to infection by *Cercospora beticola*. Jour. Agric. Research **5**:1011–1038. *pls. 80, 81. figs. 6.* 1916.

[28] ———, Climatic conditions as related to *Cercospora beticola*. Jour. Agric. Research **6**:21–60. *pls. 3, 4. figs. 10.* 1916.

stomatal opening, such as temperatures ranging from 70 to 90° F. and high humidity, also chance to favor maximal germination of spores and subsequent growth and therefore lead to severe leaf infection. Such studies as these will do much to lift the fog that shrouds the problem of infection in the field of phytopathology. The term "stomatal movement," of the title, is somewhat unfortunately chosen. The authors have established a relation between infection and stomatal opening rather than between infection and stomatal movement.—GEORGE K. K. LINK.

Addisonia.—This is the title of a new journal issued from the New York Botanical Garden devoted to "colored illustrations and popular descriptions of plants." It is issued quarterly, the first number bearing the date March 1916, and each number will consist of 10 colored plates with accompanying letter press. The subsidy for the journal is furnished by a fund left for this purpose by Judge ADDISON BROWN. This explains the name and also the color of the cover. The annual subscription price is $10. The illustrations and letter press of the initial number are of the highest order, the plants illustrated and described being *Rhododendron carolinianum*, *Cassia polyphylla*, *Robinia Kelseyi*, *Pachyphytum longifolium*, *Begonia Cowellii*, *Echeveria setosa*, *Columnea gloriosa*, *Fouquieria formosa*, *Maxillaria ringens*, and *Nopalea Auberi*.—J. M. C.

Dimery in Brassica.—Cases in which two or more genetic factors produce independently a single somatic character, or modify it in such a manner as not to destroy its identity, are being reported frequently. HALLQVIST[29] gives the results of crossing a form of *Brassica Napus* characterized by undivided leaves, with a form having strongly pinnatifid lobing. The F_2 families showed several grades of lobing in different plants, and in 493 individuals out of 8,296 the recessive unlobed type reappeared, this being almost exactly 1:15. All of the 23 separate F_2 families which make up this total likewise show a very close approximation to the same ratio. The investigation is being continued into the F_3.—GEO. H. SHULL.

Pollen sterility and hybrids.—GATES and GOODSPEED[30] have tested the claim that "bad pollen" is a criterion of hybridity by examining certain geographically isolated Californian plants which have had no opportunity for crossing. *Trillium sessile giganteum*, *Scoliopus Bigelovii*, *Dirca occidentalis*, *Ranunculus californicus*, and *Fritillaria lanceolata floribunda* were selected for examination, and remarkably high percentages of bad pollen were obtained. Their conclusion is that such pollen is not necessarily an indication of

[29] HALLQVIST, CARL, Ein neuer Fall von Dimerie bei *Brassica Napus*. Bot. Not. 1:39–42. 1916.

[30] GATES, R. R., and GOODSPEED, T. H., Pollen sterility in relation to crossing. Science 43:859–861. 1916.

hybridization, but that pollen sterility is a physiological condition which may be due to a variety of causes, hybridization and mutability being only two of them.—J. M. C.

Codium mucronatum.—Miss HURD[31] has made a study of *Codium mucronatum* from Puget Sound material, to establish the characteristics on the basis of which this species may be distinguished from other species, and to determine whether the division of this species into varieties (*californicum* J. G. Agardh and *novaezelandiae* J. G. Agardh) is justified. The study is a careful one and the plates will prove valuable to students of this genus. She suggests a detailed description for the species and concludes that the splitting of the species into varieties on the basis of the mucoronate tips of the utricles is not justified, since all of the described types are often found on the same plant.—GEORGE B. RIGG.

Röntgen rays.—KOERNICKE[32] finds that a small dosage of Röntgen rays accelerates growth of seeds and seedlings. In larger amounts it has no effect, while in still larger amounts it inhibits growth. In this regard Röntgen rays act like other rays and like toxic materials in general. *Vicia Faba* was especially favorable material for experimentation. Contrary to the claims of SCHWARZ, the effect of a stimulative dose at the seed or seedling stage was lost before maturity was reached. From the results of SCHWARZ, KOERNICKE had thought that Röntgen rays might be applied profitably in practice for increasing yield, but his work shows that this is not the case.—WILLIAM CROCKER.

Trigonocarpus and Ginkgo.—In 1914 SALISBURY[33] published an account of a new species of *Trigonocarpus*, and compared it with the seeds of *Ginkgo*. Later, Miss AFFOURTIT and Miss LA RIVIÈRE[34] investigated the seeds of *Ginkgo* and gave reasons for the belief that such a comparison is not valid. SALISBURY[35] has published a brief note in reply, pointing out more specifically the reasons for his view, and concludes that in the more important features of general organization the ovules of Ginkgoales, Cycadales, and *Trigonocarpus* exhibit a uniformity of construction difficult to explain except on the basis of affinity.—J. M. C.

[31] HURD, ANNIE M., *Codium mucronatum*. Puget Sound Marine Sta. Publ. **1**: 109–135. *pls. 19–24*. 1916.

[32] KOERNICKE, M., Über die Wirkung verschieden starker Röntgenstrahlen auf Keimung und Wachstum bei den höheren Pflanzen. Jahrb. Wiss. Bot. **56**:416–430. 1915. PFEFFER's Festschrift.

[33] Review in BOT. GAZ. **57**:440. 1914.

[34] Review in BOT. GAZ. **61**:176. 1916.

[35] SALISBURY, E. J., On the relation between *Trigonocarpus* and *Ginkgo*. Ann. Botany **30**:356. 1916.